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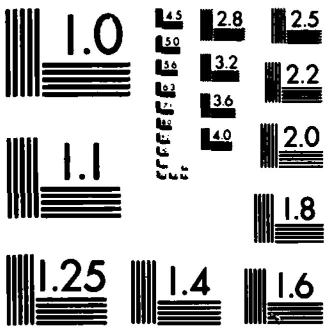

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AD-A134090

INSTRUCTION REPORT K-83-4

USER'S GUIDE FOR A PLANE AND AXISYMMETRIC FINITE ELEMENT PROGRAM FOR STEADY-STATE SEEPAGE PROBLEMS

by

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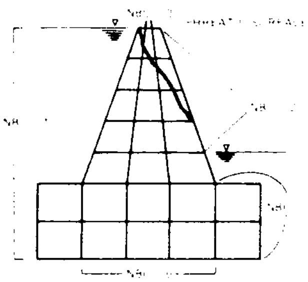

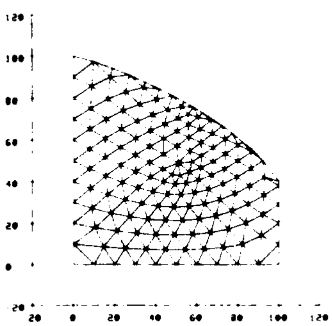

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

September 1983
Final Report

Approved For Public Release; Distribution Unlimited

Prepared for U. S. Army Engineer Division, Lower Mississippi Valley
Vicksburg, Miss 39180

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Instruction Report K-83-4	2. GOVT ACCESSION NO. AD-A134090	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) USER'S GUIDE FOR A PLANE AND AXISYMMETRIC FINITE ELEMENT PROGRAM FOR STEADY-STATE SEEPAGE PROBLEMS		5. TYPE OF REPORT & PERIOD COVERED Final report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Fred T. Tracy		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Automatic Data Processing Center P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer Division, Lower Mississippi Valley P. O. Box 80, Vicksburg, Miss. 39180		12. REPORT DATE September 1983 13. NUMBER OF PAGES 58
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer applications
Computer programs
Finite element method
Laminar flow
Seepage

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is a user's guide for a plane and axisymmetric finite element method (FEM) computer program for solving steady-state seepage problems. Confined or unconfined, homogeneous or nonhomogeneous, and isotropic or anisotropic problems can be solved. Laplace's Equation and Darcy's Law, the equations governing laminar flow through porous media, are the basis for the analysis. —>cont

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20. ABSTRACT (Continued).

Input to the program consists basically of permeability data, node data, and element data. Output from the program consists of heads at the nodes, discharge velocities at the element centers, and a postprocessor file. For unconfined problems, a description of the resulting phreatic surface is also given.

The report also contains some sample problems and a brief description of the theory.

PREFACE

This user's guide documents a computer program that uses a plane and axisymmetric finite element method of analysis for solution of steady-state seepage problems. This report provides updated information on the original two-dimensional seepage program developed for the U. S. Army Engineer Division, Lower Mississippi Valley (LMVD). This report supersedes the original report which was published as U. S. Army Engineer Waterways Experiment Station (WES) Miscellaneous Paper K-73-4, dated May 1973, entitled "A Plane and Axisymmetric Finite Element Program for Steady-State and Transient Seepage Problems." The work in enhancing the program and updating this report was accomplished as part of the applications support provided by the WES Automatic Data Processing (ADP) Center to LMVD.

The work in modifying the computer program and preparing the user's guide was done by Mr. Fred T. Tracy, Chief, Research and Development Software Group, ADP Center.

Work on the program was coordinated with LMVD and the U. S. Army Engineer Districts, St. Louis (LMS) and Vicksburg (LMK). Liaison was maintained between LMVD, LMS, LMK, and WES by means of informal meetings and telephone conversations with Mr. Tony Young, LMVD; Mr. Tom Wolff, LMS; and Mr. Eugene Wardlaw, LMS, all of which provided technical guidance in defining the desired program modifications. Mr. Wardlaw was also very helpful in testing the program.

Dr. N. Radhakrishnan, Special Technical Assistant, ADP Center, and Mr. Paul K. Senter, Computer-Aided Design Group, ADP Center, coordinated the work.

Commanders and Directors of WES during this period were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet per minute	0.2831685	cubic meters per minute
feet	0.3048	meters
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter

USER'S GUIDE FOR A PLANE AND AXISYMMETRIC FINITE ELEMENT PROGRAM FOR STEADY-STATE SEEPAGE PROBLEMS

PART I: INTRODUCTION

Background

1. The finite element method (FEM) is an outstanding numerical tool for solving two-dimensional seepage problems. It is naturally suited to solving problems involving complex geometries or nonhomogeneous and anisotropic soils. Unconfined flow problems can also be solved by using a FEM program to automatically determine the position of the phreatic surface.

2. To take advantage of the FEM for Lower Mississippi Valley Division (LMVD) seepage problems, a computer program and report, "A Plane and Axisymmetric Finite Element Program for Steady-State and Transient Seepage Problems," were written in 1973.* The program provided the following unique capabilities:

   a. Allowing the free surface to cross boundaries of different soil layers.

   b. Solving a partially confined and partially unconfined problem.

   c. Relieving restrictions on how to number the grid for unconfined flow problems.

   d. Computing the flows at the entrance and exit boundaries.

3. However, some problems were noticed in the program:

   a. Inputting incorrect phreatic surface data caused the program to stop executing.

   b. Transient and steady-state problems were computed in the same way. Thus, the steady-state solution was inefficient, and most of the problems solved by LMVD using this program were steady-state problems.

   c. Triangular elements were not allowed with the free surface, and the quadrilateral elements had to be numbered a certain way.

4. Further, some improvements were suggested to make the program more useful:

   a. Provide automatic convergence for steady-state problems.

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* Miscellaneous Paper K-73-4, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

b. Simplify input boundary codes for unconfined flow problems.

5. Therefore, a modified version of the original seepage program has been written for steady-state problems only. This new version has the following advantages:

a. Automatic convergence.

b. Easy determination of boundary codes.

c. No initial guess of the phreatic surface required.

d. No restrictions on how the grid is numbered or whether triangular elements are used.

Scope

6. This report is basically an update of the report (Miscellaneous Paper K-73-4) on the original program. Thus, it is a user's guide for the new version of the seepage program. Minor differences in input data between the old version and this new, updated version are given.

PART II: USER'S GUIDE

Computer Program Requirements

7. The program is written in FORTRAN IV. It requires 40K words of core memory, four scratch disc files (logical units 01, 02, 04, and 07), and a permanent disc file for postprocessor output (logical unit 12). Its Engineering Computer Program Library (ECPL) number is 704-F3-R0-011.

Consistent Units

8. Before the actual data are described, it should be emphasized that data must be input in consistent units. For example, if head is specified in feet and time in minutes, then the following units must be used:

a. Permeability--ft/min.

b. Discharge velocity--ft/min.

c. (x,y) node point data--ft.

Thus, if length (L) is initially given in feet and time (T) in minutes, all subsequent input (and output) data must use the same units.

Description of Input Data

9. The following input data cards are required for each problem. Any number of problems can be solved by the same computer run by simply stacking problem data sets sequentially. In the section to follow, two items for each type of data are supplied to aid users who are familiar with FORTRAN language and FORMAT statements. The first item gives the format specifications (shown in brackets after the side headings) under which the data are input. The second item states the names (variables) used in the program to retain the data.

Title card [13A6, A2]

10. This is an identification card for the problem:

Column	Variable	Description
1-80	HED	Alphanumeric identification

Any legal FORTRAN character is permissible. The title appears on the printed output of the program.

Control card [4I5, 1X, A4, F10.0]

11. This card controls the size and type of problem:

Column	Variable	Description
1-5	NUMNP	Number of node points. NUMNP cannot be greater than 1000
6-10	NUMEL	Number of elements. NUMEL cannot be greater than 950
11-15	NUMMAT	Number of soil types. NUMMAT cannot be greater than 12
16-20	NFLCD	Number of discharge velocity cards (see paragraph 19)
22-25	LPLX	Type of problem. Input PLNE for plane flow or AXSY for axisymmetric flow
26-35	DATUM	Elevation of datum (L). The datum is defined by $H = \frac{P}{\gamma_w} + Y - D$ H is the total head, P is the pressure, γ_w is the density of water, Y is the y coordinate, and D is the datum. The datum is an arbitrary constant and is typically set to zero. However, in well problems it can be set to the height of the headwater level, thus making the total head negative and corresponding to drawdown

This list is shorter than that for the old version of the program because the transient data of time increment (DELTAT) and print interval (IPRNT) have been removed. Also, a declaration of whether the problem is confined or unconfined (LTYPE) is no longer needed since the program determines this automatically. Infiltration rate (RINFL) has also been removed.

Soil cards [I5, 2F10.0]

12. These cards describe the characteristics of soil types in the problem. One card is required for each soil type:

Column	Variable	Description
1-5	I	Soil type number. Soil cards must be in ascending order with respect to soil type number
6-15	XK1(I)	First principal permeability (L/T)
16-25	XK2(I)	Second principal permeability (L/T)

The only difference in this list and the old one is that the storage coefficient for each material type (STOR(I)) is omitted because this information was needed only for transient problems.

Nodal point cards [I5, I2, I3, 3F10.0]

13. These cards give required information for the nodes:

Column	Variable	Description
1-5	N	Nodal point number
6-7	IN	Boundary condition flag for generated nodes of a line segment, the first node of which is N. If IN = 0, all boundary condition information is set to zero. If IN = 1, the type of boundary condition for generated nodes is set to the value at node N. The boundary value for generated nodes is determined by linear interpolation if IN = 1 or is set to zero if JN = 0
8-10	NBC(N)	Boundary condition flag. NBC = 0 for an internal node or an impervious boundary node; NBC = 1 for a specified head on a boundary; and NBC = -1 for a specified flow on a boundary. For unconfined flow problems, use NBC = 2 for the exit face (see Figure 1). Be sure to include all nodes from the top of the face, down to and including the node at the tailwater level
11-20	X(N)	x value (L) of node point
21-30	Y(N)	y value (L) of node point

(Continued)

Column	Variable	Description
31-40	FX(N)	Boundary value. FX represents head (L) for positive NBC and flow per unit length (L^2/T) for plane problems or flow per unit radian (L^3/T) for axisymmetric problems for negative NBC

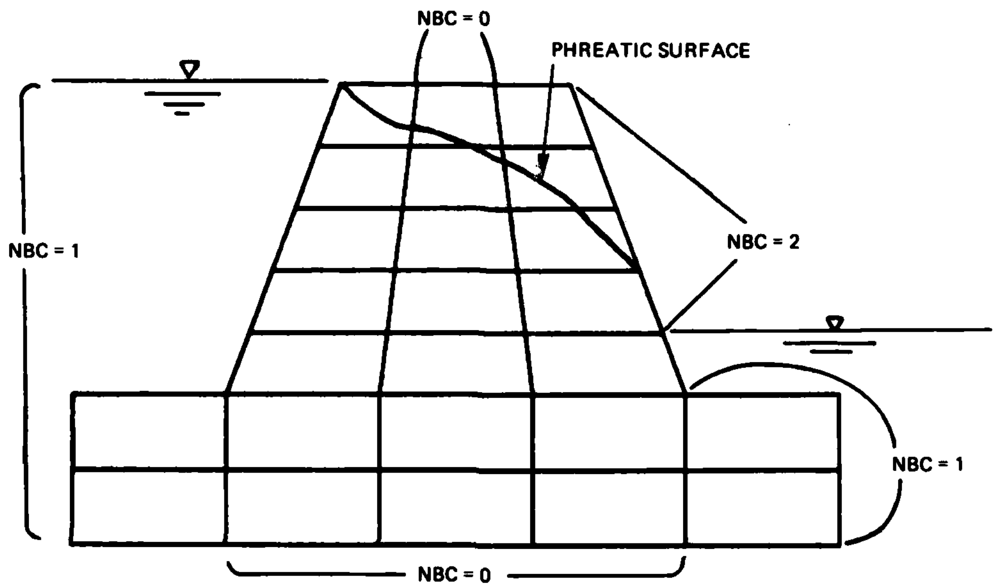

Figure 1. Unconfined flow boundary codes

One card per node is required unless a set of consecutively numbered nodes is located at equal intervals along a straight-line segment (see Figure 2). In this case, nodal point data for the interior nodes of the line segment (nodes 5-8) are generated if node cards for these points are omitted. Thus, for the example in Figure 2, the card for node 4 should be followed by a card for node 9. The coordinates of the generated nodes are found by linearly interpolating between the coordinates of the first node (4) and the last node (9) of the line segment. The type of boundary condition for the generated nodes is set either to zero or to the value of the first node (see variable IN above). Boundary values for generated nodes either are determined by linearly interpolating between the first and last nodes of a line segment or are set to zero.

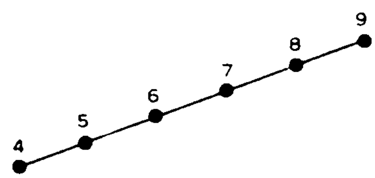

Figure 2. Line of nodes

14. Node cards must be numbered in ascending order with respect to node number, and the number of the first node must be 1. A data card for both the first and last nodes must always be supplied. The old version of the program requested a rate of change of boundary condition value for each node (DELFX(N)). This item has been dropped from the list because it is used only for transient problems. The meanings of the NBC values have also been simplified.

Phreatic surface data

15. The old version of the program required an initial guess as to the phreatic surface. The new version determines this automatically, so these data are no longer required.

Element cards [6I5, F10.0]

16. These cards contain the information about the elements:

Column	Variable	Description
1-5	J	Element number
6-10	NP(1,J)	First node of element J. The nodes must be in counterclockwise order as shown in Figure 3. In this example, the nodes could be rendered 5, 10, 11, 6
11-15	NP(2,J)	Second node of element J
16-20	NP(3,J)	Third node of element J
21-25	NP(4,J)	Fourth node of element J
26-30	NP(5,J)	Soil type number
31-40	ANG(J)	Angle (in degrees) between the first principal permeability and the x axis as shown in Figure 4; k_1 and k_2 represent the two principal permeabilities

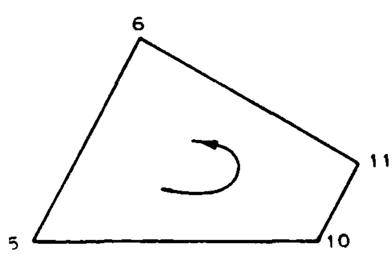

Figure 3. Counterclockwise numbering

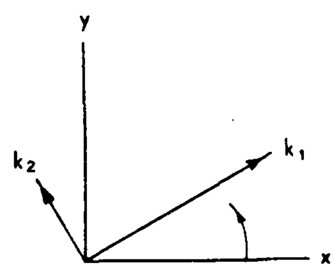

Figure 4. Principal permeabilities

One card per element is needed unless a group of elements satisfies the following conditions:

a. The soil type and two directions of the principal permeabilities are the same for all elements of a group.

b. Element numbers of a group are consecutive.

c. Node numbers for elements N+1 of a group can be generated by incrementing the node numbers of element N by 1.

In this case, element data for all but the first element of a group are generated if cards for these elements are omitted. For example, elements 3-5 of the configuration in Figure 5 form a group. The data cards for element 3 should therefore be followed by a data card for element 6. The soil type and directions of the principal permeabilities for generated elements are set to the respective values of the first element (element 3) of a group. Node numbers for generated elements are produced by successively incrementing the respective node numbers of the first element of a group by 1.

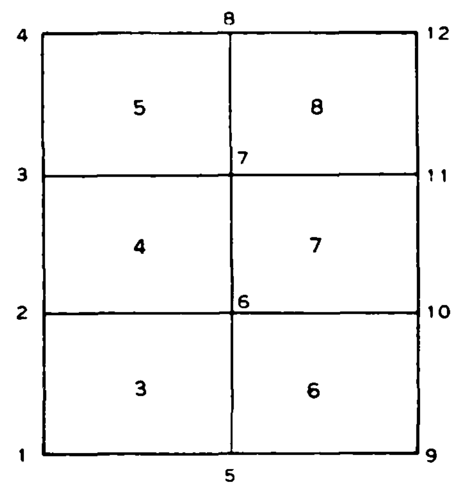

Figure 5. Sample grid

17. Element cards must be numbered in ascending order with respect to element number, and the number of the first element must be 1. A data card for both the first and last elements must always be supplied.

18. During initial setup of the problem, the user should attempt to assign node numbers to the elements in such a way as to minimize the difference between the largest and the smallest node numbers of each element. This so-called "greatest difference" cannot be greater than 59. The old version of the program required special numbering of elements, and no triangular elements were allowed wherever the phreatic surface would potentially go. In the new version, these restrictions no longer apply.

Discharge velocity cards [2I5, F10.0]

19. The discharge velocity cards are used to specify discharge velocity along straight-line segments connecting two nodes:

Column	Variable	Description
1-5	K	First node of line segment
6-10	L	Second node of line segment
11-20	FLRT	Normal component of discharge velocity (L/T) on line segment. A positive value for FLRT indicates that the flow is entering the system; a negative value indicates exit

One card for each line segment is required. The total number of discharge velocity cards must equal NFLCD. If NFLCD is zero, no cards are needed. NBC(K) and NBC(L) must be set to -1 in the nodal point data.

Description of Output Data

20. Output is in the form of printed information and a postprocessor file. Four groups of printed information are supplied:

a. Input data.

b. Heads and flows at nodes.

c. Discharge velocities (flow rates) for the elements.

d. Phreatic surface and iteration information for unconfined flow problems.

Input data

21. The problem identification, soil information, nodal point information, element information, and flow rate data are first printed. These data are included for all generated nodes and elements. A printed copy of the input data is valuable for verifying that the intended data were supplied.

Heads and flows

22. The head at every node is printed. Since seepage results from a head differential rather than from the magnitude of head, the percentage of net head is also printed for every node. Flow entering or leaving the flow region is provided for every boundary node. As shown in Figure 6, flow at a node is the quantity of water per unit time per unit length (plane flow) or per unit radian (axisymmetric flow) crossing the boundary through the effective area surrounding the node. A positive flow indicates flow entering the system, and a negative flow indicates exit.

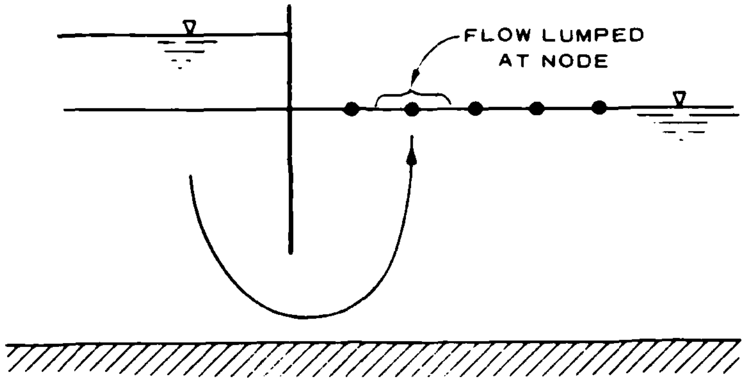

Figure 6. Flow

Discharge velocities

23. The discharge velocities at $\bar{X}^e$, $\bar{Y}^e$ in the k_1 and k_2 directions, respectively, are printed for each element in the flow region. The value $\bar{X}^e$, $\bar{Y}^e$ is the average of the x's and y's, respectively, of the element corner nodes. If the phreatic surface crosses a group of elements as shown in Figure 7, the coordinates of the nodes of these elements are temporarily changed to coincide with the phreatic surface. Elements outside the flow region are therefore eliminated, and $\bar{X}^e$, $\bar{Y}^e$ is altered for some elements.

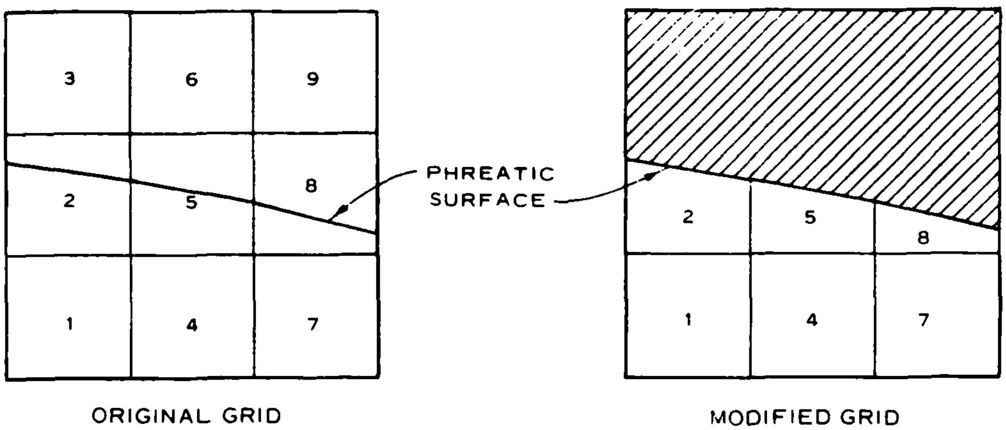

Figure 7. Phreatic surface intersecting the grid

24. The magnitude and direction of the discharge velocity are also printed. The direction is specified by the counterclockwise angle between the x axis and the discharge velocity direction.

Phreatic surface and
iteration information

25. Phreatic surface. The status of each node with respect to the

phreatic surface is printed. (See Appendix A for details on how these data are computed.) Two questions are answered by this output:

a. Is the node above, below, or part of the phreatic surface?

b. If the node is a phreatic surface node (a node just above or on the phreatic surface whose coordinates have been temporarily modified so that the node now rests on the phreatic surface), what are its temporary coordinates?

26. Iteration information. For each iteration, the maximum change in head at the nodes inside the flow region over head for the previous iteration is printed.

Postprocessor file

27. The postprocessor file is used to obtain the modified grid, equipotential, and discharge velocity vector plots. It is a line-numbered file and consists of:

a. A line containing the number of nodes and elements.

b. A line for each node containing the node number, x coordinate, y coordinate, total head, and percentage of net effective head.

c. A line for each element containing the element number, average x and average y values of the node coordinates, the four node numbers, and the x and y components of discharge velocity.

PART III: SAMPLE PROBLEMS

Problem 1: Unconfined Flow in a Bank with Vertical Sides After Sudden Drawdown--Dupuit's Problem

Problem description

28. The problem deals with a bank having vertical sides where the headwater and tailwater are initially the same until the tailwater level is suddenly lowered (see Figure 8). The problem consists of determining the phreatic surface, head distribution, and quantity of flow after steady-state conditions have been reached.

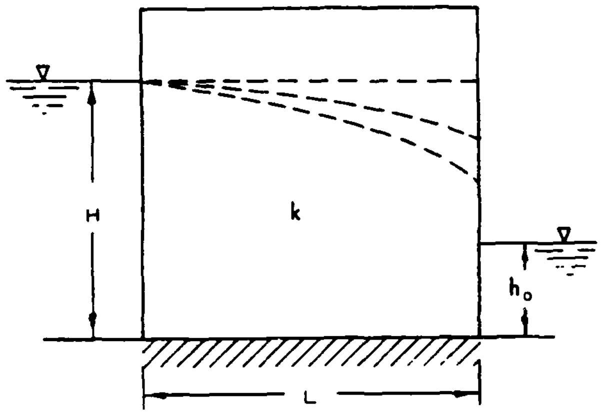

Figure 8. Dupuit's problem

Values of the constants are

$$H = 100 \text{ ft*}$$
$$h_o = 20 \text{ ft}$$
$$L = 100 \text{ ft}$$
$$k = 0.1 \text{ ft/min}$$

Finite element grids

29. Two different FE grids are used to solve this problem: a small rectangular grid (Figure 9), and a large triangular grid (Figure 10).

---

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

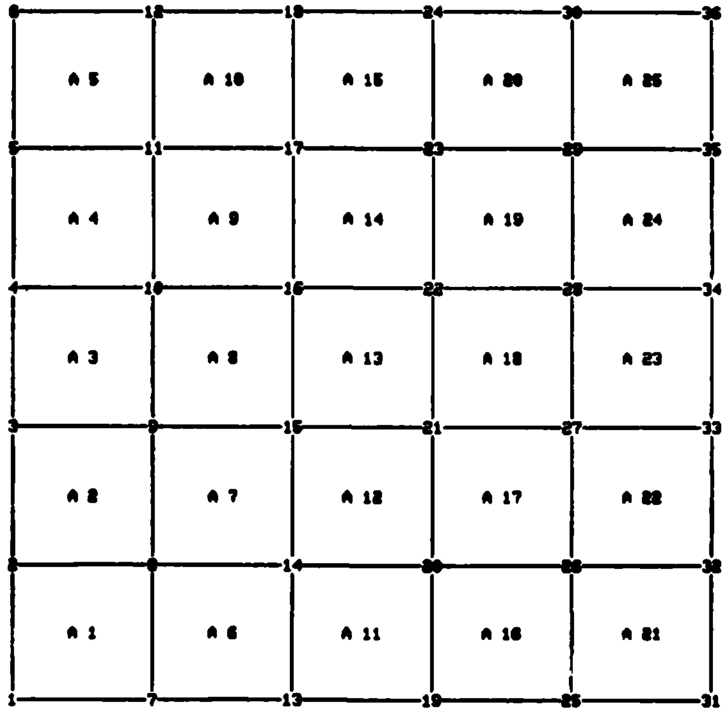

Figure 9. Small rectangular grid

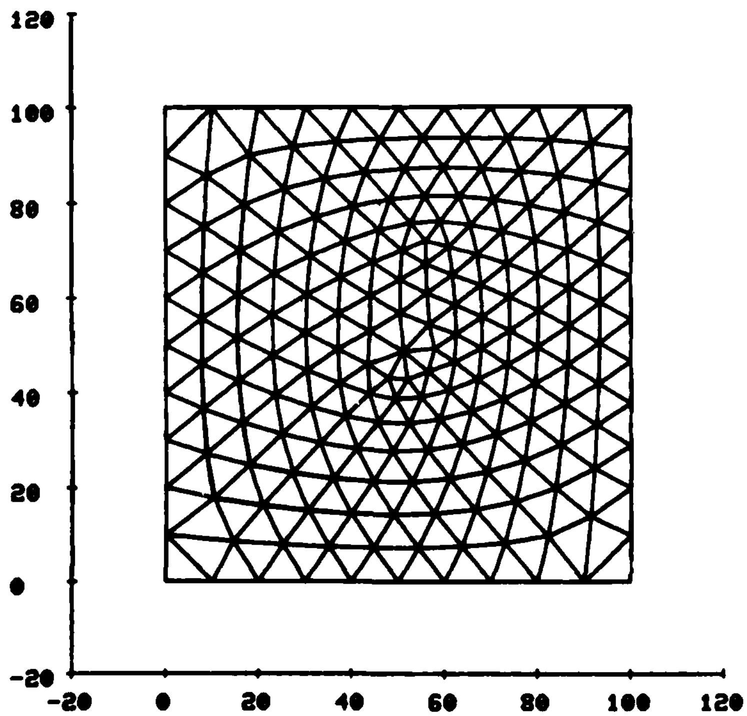

Figure 10. Large triangular grid

Input cards

30. A listing of the input cards for the rectangular grid is given below.

```
DUPUIT'S PROBLEM
  36    25     1      0 PLNE          0.
   1           .1          .1
   1  1   1          0.         0.        100.
   6      1          0.       100.        100.
   7                20.         0.
  12                20.       100.
  13                40.         0.
  18                40.       100.
  19                60.         0.
  24                60.       100.
  25                80.         0.
  30                80.       100.
  31      1        100.         0.         20.
  32  1   2        100.        20.         20.
  36      2        100.       100.        100.
   1      1      7      8      2      1
   6      7     13     14      8      1
  11     13     19     20     14      1
  16     19     25     26     20      1
  21     25     31     32     26      1
  25     29     35     36     30      1
```

Output

31. A listing of the output for the rectangular grid is presented below.

```
                              PLANE FLOW PROBLEM

DUPUIT'S PROBLEM



 NUMBER OF NODAL POINTS------ 36

 NUMBER OF ELEMENTS---------- 25

 NUMBER OF DIFF. MATERIALS---  1

 ELEVATION OF DATUM----------     0.

                                    MATERIAL PROPERTIES

                          MAT           K1                 K2

                           1        0.100E 00          0.100E 00
```

NODE POINT INFORMATION

NODE	BC	X	Y	FLOW-HEAD
1	1	0.	0.	100.00
2	1	0.	20.00	100.00
3	1	0.	40.00	100.00
4	1	0.	60.00	100.00
5	1	0.	80.00	100.00
6	1	0.	100.00	100.00
7	0	20.00	0.	0.
8	0	20.00	20.00	0.
9	0	20.00	40.00	0.
10	0	20.00	60.00	0.
11	0	20.00	80.00	0.
12	0	20.00	100.00	0.
13	0	40.00	0.	0.
14	0	40.00	20.00	0.
15	0	40.00	40.00	0.
16	0	40.00	60.00	0.
17	0	40.00	80.00	0.
18	0	40.00	100.00	0.
19	0	60.00	0.	0.
20	0	60.00	20.00	0.
21	0	60.00	40.00	0.
22	0	60.00	60.00	0.
23	0	60.00	80.00	0.
24	0	60.00	100.00	0.
25	0	80.00	0.	0.
26	0	80.00	20.00	0.
27	0	80.00	40.00	0.
28	0	80.00	60.00	0.
29	0	80.00	80.00	0.
30	0	80.00	100.00	0.
31	1	100.00	0.	20.00
32	2	100.00	20.00	20.00
33	2	100.00	40.00	40.00
34	2	100.00	60.00	60.00
35	2	100.00	80.00	80.00
36	2	100.00	100.00	100.00

ELEMENT INFORMATION

ELMT	#1	#2	#3	#4	MAT	ANGLE
1	1	7	8	2	1	0.
2	2	8	9	3	1	0.
3	3	9	10	4	1	0.
4	4	10	11	5	1	0.
5	5	11	12	6	1	0.
6	7	13	14	8	1	0.
7	8	14	15	9	1	0.
8	9	15	16	10	1	0.
9	10	16	17	11	1	0.
10	11	17	18	12	1	0.
11	13	19	20	14	1	0.
12	14	20	21	15	1	0.
13	15	21	22	16	1	0.
14	16	22	23	17	1	0.
15	17	23	24	18	1	0.
16	19	25	26	20	1	0.
17	20	26	27	21	1	0.
18	21	27	28	22	1	0.
19	22	28	29	23	1	0.
20	23	29	30	24	1	0.
21	25	31	32	26	1	0.
22	26	32	33	27	1	0.
23	27	33	34	28	1	0.
24	28	34	35	29	1	0.
25	29	35	36	30	1	0.

NODAL FLOWS AND HEADS — POSITION OF PHREATIC SURFACE

NODE	HEAD	PERCENTAGE OF AVAILABLE HEAD	FLOW	ABOVE	ON	BELOW	X	Y
1	0.1000E 03	100.0 %	0.6026E 00			*		
2	0.1000E 03	100.0 %	0.1173E 01			*		
3	0.1000E 03	100.0 %	0.1082E 01			*		
4	0.1000E 03	100.0 %	0.9408E 00			*		
5	0.1000E 03	100.0 %	0.7499E 00			*		
6	0.1000E 03	100.0 %	0.2638E 00		*		0.	100.00
7	0.8772E 02	84.7 %				*		
8	0.8807E 02	85.1 %				*		
9	0.8904E 02	86.3 %				*		
10	0.9049E 02	88.1 %				*		
11	0.9234E 02	90.4 %				*		
12	0.9393E 02	92.4 %			*		20.00	93.93
13	0.7470E 02	68.4 %				*		
14	0.7548E 02	69.3 %				*		
15	0.7762E 02	72.0 %				*		
16	0.8065E 02	75.8 %				*		
17	0.8423E 02	80.3 %				*		
18	0.8492E 02	81.1 %			*		40.00	84.92
19	0.6000E 02	50.0 %				*		
20	0.6140E 02	51.8 %				*		
21	0.6525E 02	56.6 %				*		
22	0.7059E 02	63.2 %				*		
23	0.7437E 02	68.0 %			*		60.00	74.37
24				*				
25	0.4160E 02	27.0 %				*		
26	0.4498E 02	31.2 %				*		
27	0.5159E 02	39.5 %				*		
28	0.5951E 02	49.4 %			*		80.00	59.51
29				*				
30				*				
31	0.2000E 02	0. %	-0.1192E 01			*		
32	0.2000E 02	0. %	-0.2938E 01			*		
33	0.4000E 02	25.0 %	-0.6832E 00			*		
34	0.4035E 02	25.4 %			*		100.00	40.35
35				*				
36				*				

ELEMENT FLOW RATES

ELMT	V1	V2	P-AXIS ANG	RES V	DIR OF V
1	0.605E-01	-0.864E-03	0.	0.605E-01	-0.818E 00
2	0.572E-01	-0.242E-02	0.	0.573E-01	-0.242E 01
3	0.512E-01	-0.362E-02	0.	0.513E-01	-0.404E 01
4	0.429E-01	-0.463E-02	0.	0.432E-01	-0.615E 01
5	0.336E-01	-0.469E-02	0.	0.339E-01	-0.795E 01
6	0.640E-01	-0.280E-02	0.	0.641E-01	-0.250E 01
7	0.600E-01	-0.778E-02	0.	0.605E-01	-0.738E 01
8	0.531E-01	-0.112E-01	0.	0.543E-01	-0.119E 02
9	0.448E-01	-0.136E-01	0.	0.469E-01	-0.168E 02
10	0.401E-01	-0.121E-01	0.	0.419E-01	-0.168E 02
11	0.719E-01	-0.543E-02	0.	0.721E-01	-0.432E 01
12	0.661E-01	-0.150E-01	0.	0.678E-01	-0.128E 02
13	0.561E-01	-0.209E-01	0.	0.599E-01	-0.204E 02
14	0.468E-01	-0.214E-01	0.	0.515E-01	-0.246E 02
15	0.454E-01	-0.140E-01	0.	0.475E-01	-0.172E 02
16	0.871E-01	-0.120E-01	0.	0.879E-01	-0.782E 01
17	0.752E-01	-0.262E-01	0.	0.796E-01	-0.192E 02
18	0.614E-01	-0.335E-01	0.	0.700E-01	-0.286E 02
19	0.547E-01	-0.263E-01	0.	0.607E-01	-0.257E 02
21	0.116E 00	-0.846E-02	0.	0.117E 00	-0.416E 01
22	0.914E-01	-0.665E-01	0.	0.113E 00	-0.360E 02
23	0.569E-01	-0.416E-01	0.	0.705E-01	-0.362E 02

ITERATION NO. =	1	DELTA H MAX. =	0.10000000E 31
ITERATION NO. =	2	DELTA H MAX. =	0.57387257E 00
ITERATION NO. =	3	DELTA H MAX. =	0.20409732E 02
ITERATION NO. =	4	DELTA H MAX. =	0.12305222E 01
ITERATION NO. =	5	DELTA H MAX. =	0.11060864E 02
ITERATION NO. =	6	DELTA H MAX. =	0.63306427E 00
ITERATION NO. =	7	DELTA H MAX. =	0.93912921E 01
ITERATION NO. =	8	DELTA H MAX. =	0.47176266E 00
ITERATION NO. =	9	DELTA H MAX. =	0.27117305E 01
ITERATION NO. =	10	DELTA H MAX. =	0.77009296E 00
ITERATION NO. =	11	DELTA H MAX. =	0.29948235E 00
ITERATION NO. =	12	DELTA H MAX. =	0.10039425E 00
ITERATION NO. =	13	DELTA H MAX. =	0.18034458E 00
ITERATION NO. =	14	DELTA H MAX. =	0.55501938E-01

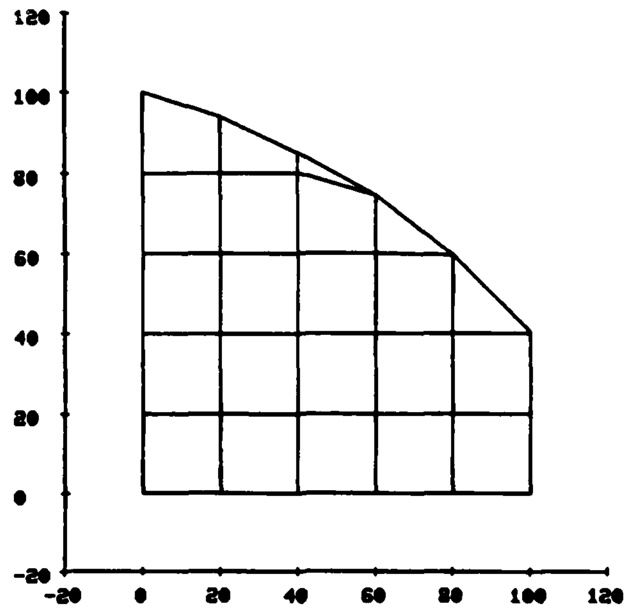

Figure 11. Modified grid plot

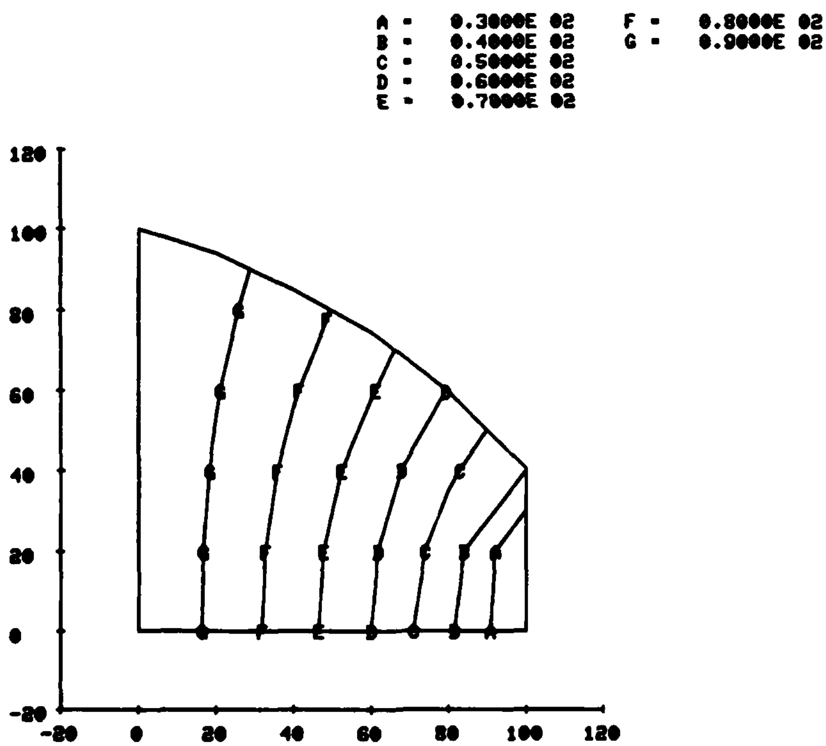

Figure 12. Equipotential line plot

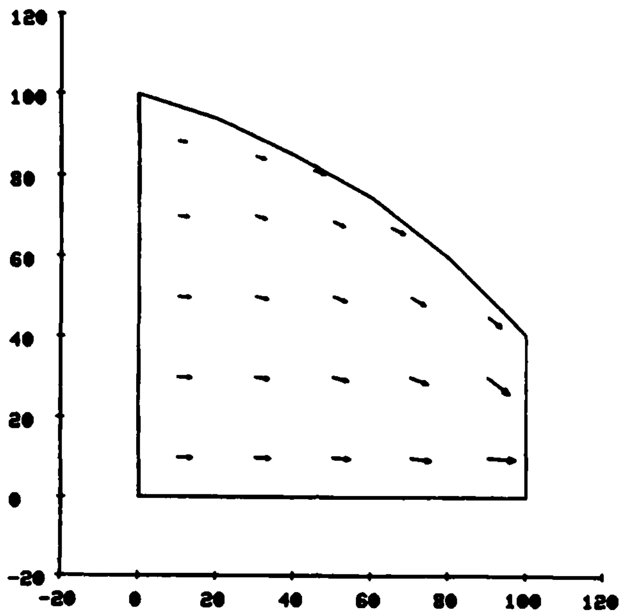

Figure 13. Velocity vector plot

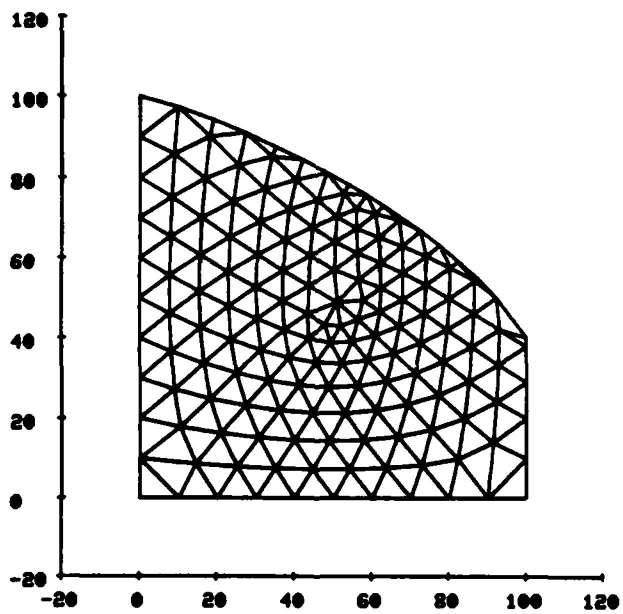

Figure 14. Modified grid plot

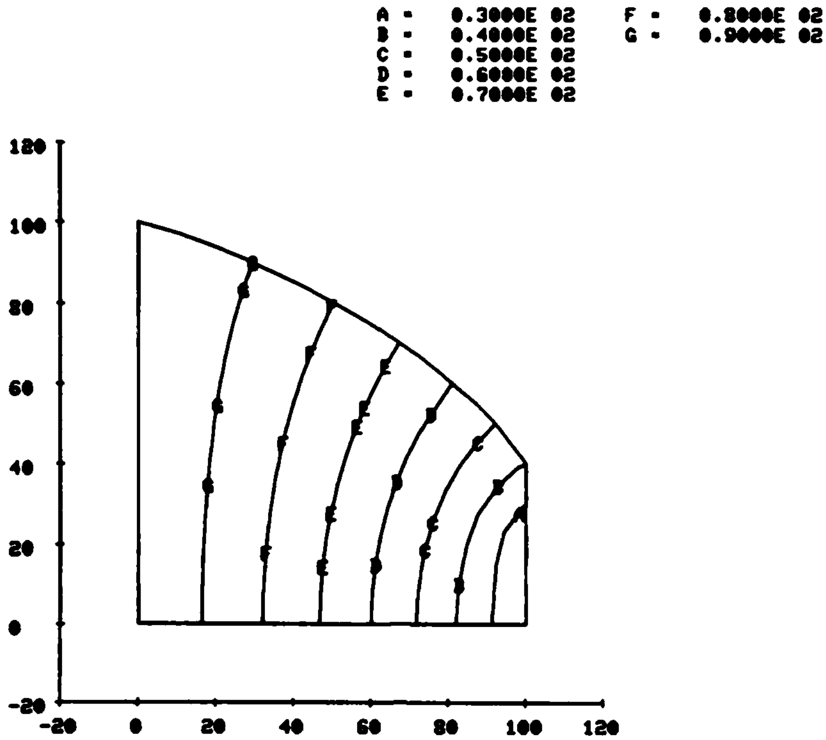

Figure 15. Equipotential line plot

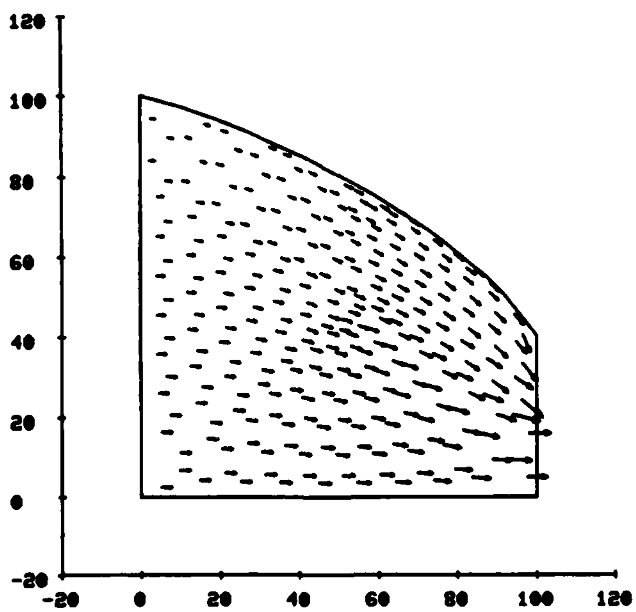

Figure 16. Velocity vector plot

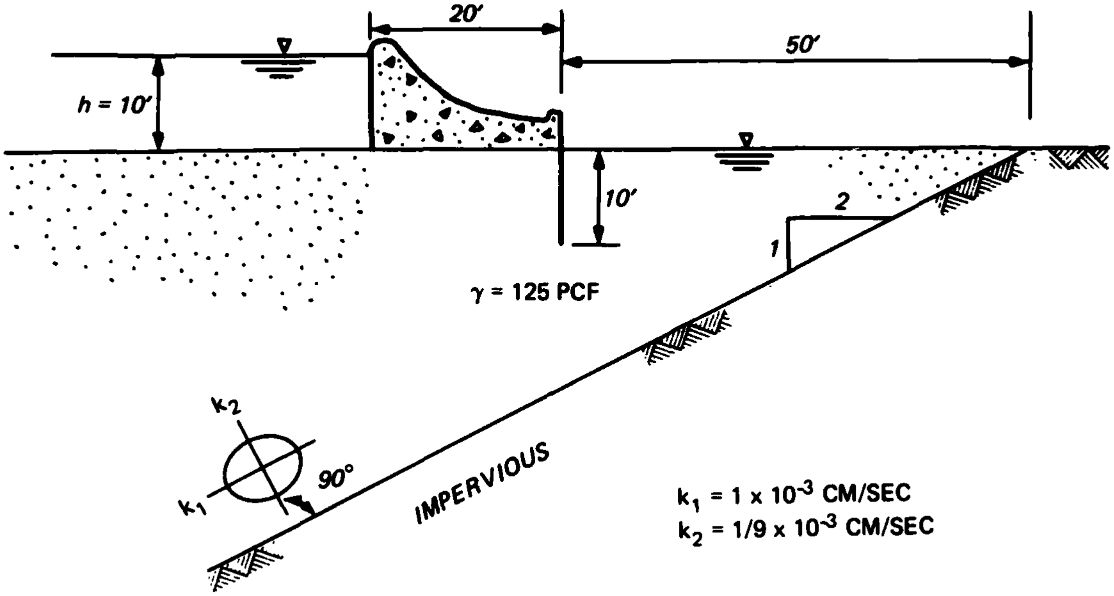

Figure 17. Weir problem

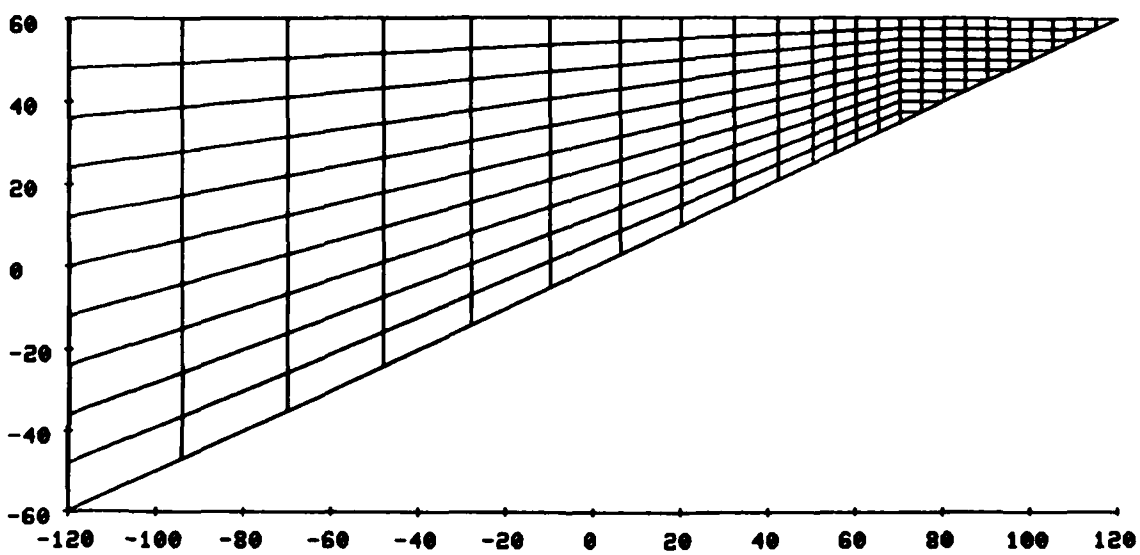

Figure 18. FE grid

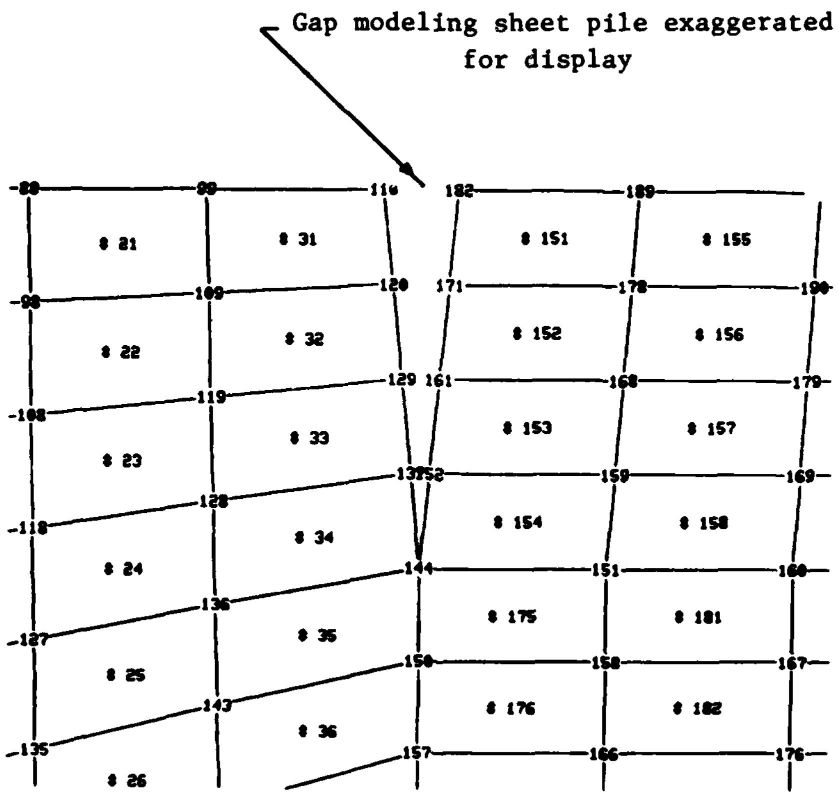

Figure 19. Model of sheet pile

Input cards

36. A listing of the input data is given below. Note that the grid being generated has a card for each node and a card for each element. Note also that units of feet and minutes are used in the problem.

```
WEIR PROBLEM
 224  195    1     0 PLNE
   1 1.9685E-3 2.1872E-4
   1     1  -120.000     60.000     70.000       0.
   2     0  -120.000     48.000     70.000       0.
   3     1   -94.000     60.000     70.000       0.
   4     0  -120.000     36.000     70.000       0.
   5     0   -94.000     49.300      0.          0.
   6     1   -70.000     60.000     70.000       0.
   7     0  -120.000     24.000     70.000       0.
   8     0   -94.000     38.600      0.          0.
   9     0   -70.000     50.500      0.          0.
  10     1   -48.000     60.000     70.000       0.
  11     0  -120.000     12.000     70.000       0.
  12     0   -94.000     27.900      0.          0.
  13     0   -70.000     41.000      0.          0.
  14     0   -48.000     51.600      0.          0.
  15     1   -28.000     60.000     70.000       0.
  16     0  -120.000      0.        70.000       0.
  17     0   -94.000     17.200      0.          0.
  18     0   -70.000     31.500      0.          0.
  19     0   -48.000     43.200      0.          0.
  20     0   -28.000     52.600      0.          0.
  21     1   -10.000     60.000     70.000       0.
  22     0  -120.000    -12.000     70.000       0.
  23     0   -94.000      6.500      0.          0.
  24     0   -70.000     22.000      0.          0.
  25     0   -48.000     34.800      0.          0.
  26     0   -28.000     45.200      0.          0.
  27     0   -10.000     53.500      0.          0.
  28     1     6.000     60.000     70.000       0.
  29     0  -120.000    -24.000     70.000       0.
  30     0   -94.000     -4.200      0.          0.
  31     0   -70.000     12.500      0.          0.
  32     0   -48.000     26.400      0.          0.
  33     0   -28.000     37.800      0.          0.
  34     0   -10.000     47.000      0.          0.
  35     0     6.000     54.300      0.          0.
  36     1    20.000     60.000     70.000       0.
  37     0  -120.000    -36.000     70.000       0.
  38     0   -94.000    -14.900      0.          0.
  39     0   -70.000      3.000      0.          0.
  40     0   -48.000     18.000      0.          0.
  41     0   -28.000     30.400      0.          0.
  42     0   -10.000     40.500      0.          0.
  43     0     6.000     48.600      0.          0.
  44     0    20.000     55.000      0.          0.
  45     1    32.000     60.000     70.000       0.
  46     0  -120.000    -48.000     70.000       0.
```

47	0	-94.000	-25.600	0.	0.
48	0	-70.000	-6.500	0.	0.
49	0	-48.000	9.600	0.	0.
50	0	-28.000	23.000	0.	0.
51	0	-10.000	34.000	0.	0.
52	0	6.000	42.900	0.	0.
53	0	20.000	50.000	0.	0.
54	0	32.000	55.600	0.	0.
55	1	42.000	60.000	70.000	0.
56	0	-120.000	-60.000	70.000	0.
57	0	-94.000	-36.300	0.	0.
58	0	-70.000	-16.000	0.	0.
59	0	-48.000	1.200	0.	0.
60	0	-28.000	15.600	0.	0.
61	0	-10.000	27.500	0.	0.
62	0	6.000	37.200	0.	0.
63	0	20.000	45.000	0.	0.
64	0	32.000	51.200	0.	0.
65	0	42.000	56.100	0.	0.
66	1	50.000	60.000	70.000	0.
67	0	-94.000	-47.000	0.	0.
68	0	-70.000	-25.500	0.	0.
69	0	-48.000	-7.200	0.	0.
70	0	-28.000	8.200	0.	0.
71	0	-10.000	21.000	0.	0.
72	0	6.000	31.500	0.	0.
73	0	20.000	40.000	0.	0.
74	0	32.000	46.800	0.	0.
75	0	42.000	52.200	0.	0.
76	0	50.000	56.500	0.	0.
77	0	55.000	60.000	0.	0.
78	0	-70.000	-35.000	0.	0.
79	0	-48.000	-15.600	0.	0.
80	0	-28.000	0.800	0.	0.
81	0	-10.000	14.500	0.	0.
82	0	6.000	25.800	0.	0.
83	0	20.000	35.000	0.	0.
84	0	32.000	42.400	0.	0.
85	0	42.000	48.300	0.	0.
86	0	50.000	53.000	0.	0.
87	0	55.000	56.750	0.	0.
88	0	59.999	60.000	0.	0.
89	0	-48.000	-24.000	0.	0.
90	0	-28.000	-6.600	0.	0.
91	0	-10.000	8.000	0.	0.
92	0	6.000	20.100	0.	0.
93	0	20.000	30.000	0.	0.
94	0	32.000	38.000	0.	0.
95	0	42.000	44.400	0.	0.
96	0	50.000	49.500	0.	0.
97	0	55.000	53.500	0.	0.

98	0	60.000	57.000	0.	0.
99	0	64.999	60.000	0.	0.
100	0	-28.000	-14.000	0.	0.
101	0	-10.000	1.500	0.	0.
102	0	6.000	14.400	0.	0.
103	0	20.000	25.000	0.	0.
104	0	32.000	33.600	0.	0.
105	0	42.000	40.500	0.	0.
106	0	50.000	46.000	0.	0.
107	0	55.000	50.250	0.	0.
108	0	60.000	54.000	0.	0.
109	0	64.999	57.250	0.	0.
110	0	69.999	60.000	0.	0.
111	0	-10.000	-5.000	0.	0.
112	0	6.000	8.700	0.	0.
113	0	20.000	20.000	0.	0.
114	0	32.000	29.200	0.	0.
115	0	42.000	36.600	0.	0.
116	0	50.000	42.500	0.	0.
117	0	55.000	47.000	0.	0.
118	0	60.000	51.000	0.	0.
119	0	64.999	54.500	0.	0.
120	0	69.999	57.500	0.	0.
121	0	6.000	3.000	0.	0.
122	0	20.000	15.000	0.	0.
123	0	32.000	24.800	0.	0.
124	0	42.000	32.700	0.	0.
125	0	50.000	39.000	0.	0.
126	0	55.000	43.750	0.	0.
127	0	60.000	48.000	0.	0.
128	0	64.999	51.750	0.	0.
129	0	70.000	55.000	0.	0.
130	0	20.000	10.000	0.	0.
131	0	32.000	20.400	0.	0.
132	0	42.000	28.800	0.	0.
133	0	50.000	35.500	0.	0.
134	0	55.000	40.500	0.	0.
135	0	60.000	45.000	0.	0.
136	0	65.000	49.000	0.	0.
137	0	70.000	52.500	0.	0.
138	0	32.000	16.000	0.	0.
139	0	42.000	24.900	0.	0.
140	0	50.000	32.000	0.	0.
141	0	55.000	37.250	0.	0.
142	0	60.000	42.000	0.	0.
143	0	65.000	46.250	0.	0.
144	0	70.000	50.000	0.	0.
145	0	42.000	21.000	0.	0.
146	0	50.000	28.500	0.	0.
147	0	55.000	34.000	0.	0.
148	0	60.000	39.000	0.	0.

149	0	65.000	43.500	0.	0.
150	0	70.000	47.500	0.	0.
151	0	75.000	50.000	0.	0.
152	0	70.000	52.500	0.	0.
153	0	50.000	25.000	0.	0.
154	0	55.000	30.750	0.	0.
155	0	60.000	36.000	0.	0.
156	0	65.000	40.750	0.	0.
157	0	70.000	45.000	0.	0.
158	0	75.000	47.500	0.	0.
159	0	75.000	52.500	0.	0.
160	0	80.000	50.000	0.	0.
161	0	70.001	55.000	0.	0.
162	0	55.000	27.500	0.	0.
163	0	60.000	33.000	0.	0.
164	0	65.000	38.000	0.	0.
165	0	70.000	42.500	0.	0.
166	0	75.000	45.000	0.	0.
167	0	80.000	47.500	0.	0.
168	0	75.000	55.000	0.	0.
169	0	80.000	52.500	0.	0.
170	0	85.000	50.000	0.	0.
171	0	70.001	57.500	0.	0.
172	0	60.000	30.000	0.	0.
173	0	65.000	35.250	0.	0.
174	0	70.000	40.000	0.	0.
175	0	75.000	42.500	0.	0.
176	0	80.000	45.000	0.	0.
177	0	85.000	47.500	0.	0.
178	0	75.001	57.500	0.	0.
179	0	80.000	55.000	0.	0.
180	0	85.000	52.500	0.	0.
181	0	90.000	50.000	0.	0.
182	1	70.001	60.000	60.000	0.
183	0	65.000	32.500	0.	0.
184	0	70.000	37.500	0.	0.
185	0	75.000	40.000	0.	0.
186	0	80.000	42.500	0.	0.
187	0	85.000	45.000	0.	0.
188	0	90.000	47.500	0.	0.
189	1	75.001	60.000	60.000	0.
190	0	80.001	57.500	0.	0.
191	0	85.000	55.000	0.	0.
192	0	90.000	52.500	0.	0.
193	0	95.000	50.000	0.	0.
194	0	70.000	35.000	0.	0.
195	0	75.000	37.500	0.	0.
196	0	80.000	40.000	0.	0.
197	0	85.000	42.500	0.	0.
198	0	90.000	45.000	0.	0.
199	0	95.000	47.500	0.	0.

200	1	80.001	60.000	60.000	0.
201	0	85.001	57.500	0.	0.
202	0	90.000	55.000	0.	0.
203	0	95.000	52.500	0.	0.
204	0	100.000	50.000	0.	0.
205	1	85.001	60.000	60.000	0.
206	0	90.000	57.500	0.	0.
207	0	95.000	55.000	0.	0.
208	0	100.000	52.500	0.	0.
209	0	105.000	52.500	0.	0.
210	1	90.001	60.000	60.000	0.
211	0	95.000	57.500	0.	0.
212	0	100.000	55.000	0.	0.
213	0	105.000	55.000	0.	0.
214	0	110.000	55.000	0.	0.
215	1	95.000	60.000	60.000	0.
216	0	100.000	57.500	0.	0.
217	0	105.000	57.500	0.	0.
218	0	110.000	57.500	0.	0.
219	0	115.000	57.500	0.	0.
220	1	100.000	60.000	60.000	0.
221	1	105.000	60.000	60.000	0.
222	1	110.000	60.000	60.000	0.
223	1	115.000	60.000	60.000	0.
224	1	120.000	60.000	60.000	0.

1	66	76	87	77	1	26.565
2	76	86	97	87	1	26.565
3	86	96	107	97	1	26.565
4	96	106	117	107	1	26.565
5	106	116	126	117	1	26.565
6	116	125	134	126	1	26.565
7	125	133	141	134	1	26.565
8	133	140	147	141	1	26.565
9	140	146	154	147	1	26.565
10	146	153	162	154	1	26.565
11	77	87	98	88	1	26.565
12	87	97	108	98	1	26.565
13	97	107	118	108	1	26.565
14	107	117	127	118	1	26.565
15	117	126	135	127	1	26.565
16	126	134	142	135	1	26.565
17	134	141	148	142	1	26.565
18	141	147	155	148	1	26.565
19	147	154	163	155	1	26.565
20	154	162	172	163	1	26.565
21	88	98	109	99	1	26.565
22	98	108	119	109	1	26.565
23	108	118	128	119	1	26.565
24	118	127	136	128	1	26.565
25	127	135	143	136	1	26.565
26	135	142	149	143	1	26.565

27	142	148	156	149	1	26.565
28	149	155	164	156	1	26.565
29	155	163	173	164	1	26.565
30	163	172	183	173	1	26.565
31	99	109	120	110	1	26.565
32	109	119	129	120	1	26.565
33	119	128	137	129	1	26.565
34	128	136	144	137	1	26.565
35	136	143	150	144	1	26.565
36	143	149	157	150	1	26.565
37	149	156	165	157	1	26.565
38	156	164	174	165	1	26.565
39	164	173	184	174	1	26.565
40	173	183	194	184	1	26.565
41	153	146	139	145	1	26.565
42	146	140	132	139	1	26.565
43	140	133	124	132	1	26.565
44	133	125	115	124	1	26.565
45	125	116	105	115	1	26.565
46	116	106	95	105	1	26.565
47	106	96	85	95	1	26.565
48	96	86	75	85	1	26.565
49	86	76	65	75	1	26.565
50	76	66	55	65	1	26.565
51	145	139	131	138	1	26.565
52	139	132	123	131	1	26.565
53	132	124	114	123	1	26.565
54	124	115	104	114	1	26.565
55	115	105	94	104	1	26.565
56	105	95	84	94	1	26.565
57	95	85	74	84	1	26.565
58	85	75	64	74	1	26.565
59	75	65	54	64	1	26.565
60	65	55	45	54	1	26.565
61	138	131	122	130	1	26.565
62	131	123	113	122	1	26.565
63	123	114	103	113	1	26.565
64	114	104	93	103	1	26.565
65	104	94	83	93	1	26.565
66	94	84	73	83	1	26.565
67	84	74	63	73	1	26.565
68	74	64	53	63	1	26.565
69	64	54	44	53	1	26.565
70	54	45	36	44	1	26.565
71	130	122	112	121	1	26.565
72	122	113	102	112	1	26.565
73	113	103	92	102	1	26.565
74	103	93	82	92	1	26.565
75	93	83	72	82	1	26.565
76	83	73	62	72	1	26.565
77	73	63	52	62	1	26.565

78	63	53	43	52	1	26.565
79	53	44	35	43	1	26.565
80	44	36	28	35	1	26.565
81	121	112	101	111	1	26.565
82	112	102	91	101	1	26.565
83	102	92	81	91	1	26.565
84	92	82	71	81	1	26.565
85	82	72	61	71	1	26.565
86	72	62	51	61	1	26.565
87	62	52	42	51	1	26.565
88	52	43	34	42	1	26.565
89	43	35	27	34	1	26.565
90	35	28	21	27	1	26.565
91	111	101	90	100	1	26.565
92	101	91	80	90	1	26.565
93	91	81	70	80	1	26.565
94	81	71	60	70	1	26.565
95	71	61	50	60	1	26.565
96	61	51	41	50	1	26.565
97	51	42	33	41	1	26.565
98	42	34	26	33	1	26.565
99	34	27	20	26	1	26.565
100	27	21	15	20	1	26.565
101	100	90	79	89	1	26.565
102	90	80	69	79	1	26.565
103	80	70	59	69	1	26.565
104	70	60	49	59	1	26.565
105	60	50	40	49	1	26.565
106	50	41	32	40	1	26.565
107	41	33	25	32	1	26.565
108	33	26	19	25	1	26.565
109	26	20	14	19	1	26.565
110	20	15	10	14	1	26.565
111	89	79	68	78	1	26.565
112	79	69	58	68	1	26.565
113	69	59	48	58	1	26.565
114	59	49	39	48	1	26.565
115	49	40	31	39	1	26.565
116	40	32	24	31	1	26.565
117	32	25	18	24	1	26.565
118	25	19	13	18	1	26.565
119	19	14	9	13	1	26.565
120	14	10	6	9	1	26.565
121	78	68	57	67	1	26.565
122	68	58	47	57	1	26.565
123	58	48	38	47	1	26.565
124	48	39	30	38	1	26.565
125	39	31	23	30	1	26.565
126	31	24	17	23	1	26.565
127	24	18	12	17	1	26.565
128	18	13	8	12	1	26.565

129	13	9	5	8	1	26.565
130	9	6	3	5	1	26.565
131	67	57	46	56	1	26.565
132	57	47	37	46	1	26.565
133	47	38	29	37	1	26.565
134	38	30	22	29	1	26.565
135	30	23	16	22	1	26.565
136	23	17	11	16	1	26.565
137	17	12	7	11	1	26.565
138	12	8	4	7	1	26.565
139	8	5	2	4	1	26.565
140	5	3	1	2	1	26.565
141	220	216	217	221	1	26.565
142	216	212	213	217	1	26.565
143	212	208	209	213	1	26.565
144	208	204	209	209	1	26.565
145	221	217	218	222	1	26.565
146	217	213	214	218	1	26.565
147	213	209	214	214	1	26.565
148	222	218	219	223	1	26.565
149	218	214	219	219	1	26.565
150	223	219	224	224	1	26.565
151	182	171	178	189	1	26.565
152	171	161	168	178	1	26.565
153	161	152	159	168	1	26.565
154	152	144	151	159	1	26.565
155	189	178	190	200	1	26.565
156	178	168	179	190	1	26.565
157	168	159	169	179	1	26.565
158	159	151	160	169	1	26.565
159	200	190	201	205	1	26.565
160	190	179	191	201	1	26.565
161	179	169	180	191	1	26.565
162	169	160	170	180	1	26.565
163	205	201	206	210	1	26.565
164	201	191	202	206	1	26.565
165	191	180	192	202	1	26.565
166	180	170	181	192	1	26.565
167	210	206	211	215	1	26.565
168	206	202	207	211	1	26.565
169	202	192	203	207	1	26.565
170	192	181	193	203	1	26.565
171	215	211	216	220	1	26.565
172	211	207	212	216	1	26.565
173	207	203	208	212	1	26.565
174	203	193	204	208	1	26.565
175	144	150	158	151	1	26.565
176	150	157	166	158	1	26.565
177	157	165	175	166	1	26.565
178	165	174	185	175	1	26.565
179	174	184	195	185	1	26.565

180	184	194	195	195	1	26.565
181	151	158	167	160	1	26.565
182	158	166	176	167	1	26.565
183	166	175	186	176	1	26.565
184	175	185	196	186	1	26.565
185	185	195	196	196	1	26.565
186	160	167	177	170	1	26.565
187	167	176	187	177	1	26.565
188	176	186	197	187	1	26.565
189	186	196	197	197	1	26.565
190	170	177	188	181	1	26.565
191	177	187	198	188	1	26.565
192	187	197	198	198	1	26.565
193	181	188	199	193	1	26.565
194	188	198	199	199	1	26.565
195	193	199	204	204	1	26.565

Output

37. A listing of the output is now given.

PLANE FLOW PROBLEM

WEIR PROBLEM

NUMBER OF NODAL POINTS------224

NUMBER OF ELEMENTS-----------195

NUMBER OF DIFF. MATERIALS--- 1

ELEVATION OF DATUM----------   0.

MATERIAL PROPERTIES

MAT	K1	K2
1	0.197E-02	0.219E-03

NODE POINT INFORMATION

NODE	BC	X	Y	FLOW-HEAD
1	1	-120.00	60.00	70.00
2	0	-120.00	48.00	70.00
3	1	-94.00	60.00	70.00
4	0	-120.00	36.00	70.00
5	0	-94.00	49.30	0.
6	1	-70.00	60.00	70.00
7	0	-120.00	24.00	70.00
8	0	-94.00	38.60	0.
9	0	-70.00	50.50	0.
10	1	-48.00	60.00	70.00
11	0	-120.00	12.00	70.00
12	0	-94.00	27.90	0.
13	0	-70.00	41.00	0.
14	0	-48.00	51.60	0.
15	1	-28.00	60.00	70.00
16	0	-120.00	0.	70.00
17	0	-94.00	17.20	0.
18	0	-70.00	31.50	0.
19	0	-48.00	43.20	0.
20	0	-28.00	52.60	0.
21	1	-10.00	60.00	70.00
22	0	-120.00	-12.00	70.00
23	0	-94.00	6.50	0.
24	0	-70.00	22.00	0.
25	0	-48.00	34.80	0.
26	0	-28.00	45.20	0.
27	0	-10.00	53.50	0.
28	1	6.00	60.00	70.00
29	0	-120.00	-24.00	70.00
30	0	-94.00	-4.20	0.
31	0	-70.00	12.50	0.
32	0	-48.00	26.40	0.
33	0	-28.00	37.80	0.
34	0	-10.00	47.00	0.
35	0	6.00	54.30	0.
36	1	20.00	60.00	70.00
37	0	-120.00	-36.00	70.00
38	0	-94.00	-14.90	0.
39	0	-70.00	3.00	0.
40	0	-48.00	18.00	0.
41	0	-28.00	30.40	0.
42	0	-10.00	40.50	0.
43	0	6.00	48.60	0.

44	0	20.00	55.00	0.
45	1	32.00	60.00	70.00
46	0	-120.00	-48.00	70.00
47	0	-94.00	-25.60	0.
48	0	-70.00	-6.50	0.
49	0	-48.00	9.60	0.
50	0	-28.00	23.00	0.
51	0	-10.00	34.00	0.
52	0	6.00	42.90	0.
53	0	20.00	50.00	0.
54	0	32.00	55.60	0.
55	1	42.00	60.00	70.00
56	0	-120.00	-60.00	70.00
57	0	-94.00	-36.30	0.
58	0	-70.00	-16.00	0.
59	0	-48.00	1.20	0.
60	0	-28.00	15.60	0.
61	0	-10.00	27.50	0.
62	0	6.00	37.20	0.
63	0	20.00	45.00	0.
64	0	32.00	51.20	0.
65	0	42.00	56.10	0.
66	1	50.00	60.00	70.00
67	0	-94.00	-47.00	0.
68	0	-70.00	-25.50	0.
69	0	-48.00	-7.20	0.
70	0	-28.00	8.20	0.
71	0	-10.00	21.00	0.
72	0	6.00	31.50	0.
73	0	20.00	40.00	0.
74	0	32.00	46.80	0.
75	0	42.00	52.20	0.
76	0	50.00	56.50	0.
77	0	55.00	60.00	0.
78	0	-70.00	-35.00	0.
79	0	-48.00	-15.60	0.
80	0	-28.00	0.80	0.
81	0	-10.00	14.50	0.
82	0	6.00	25.80	0.
83	0	20.00	35.00	0.
84	0	32.00	42.40	0.
85	0	42.00	48.30	0.
86	0	50.00	53.00	0.
87	0	55.00	56.75	0.
88	0	60.00	60.00	0.
89	0	-48.00	-24.00	0.
90	0	-28.00	-6.60	0.
91	0	-10.00	8.00	0.
92	0	6.00	20.10	0.
93	0	20.00	30.00	0.
94	0	32.00	38.00	0.

95	0	42.00	44.40	0.
96	0	50.00	49.50	0.
97	0	55.00	53.50	0.
98	0	60.00	57.00	0.
99	0	65.00	60.00	0.
100	0	-28.00	-14.00	0.
101	0	-10.00	1.50	0.
102	0	6.00	14.40	0.
103	0	20.00	25.00	0.
104	0	32.00	33.60	0.
105	0	42.00	40.50	0.
106	0	50.00	46.00	0.
107	0	55.00	50.25	0.
108	0	60.00	54.00	0.
109	0	65.00	57.25	0.
110	0	70.00	60.00	0.
111	0	-10.00	-5.00	0.
112	0	6.00	8.70	0.
113	0	20.00	20.00	0.
114	0	32.00	29.20	0.
115	0	42.00	36.60	0.
116	0	50.00	42.50	0.
117	0	55.00	47.00	0.
118	0	60.00	51.00	0.
119	0	65.00	54.50	0.
120	0	70.00	57.50	0.
121	0	6.00	3.00	0.
122	0	20.00	15.00	0.
123	0	32.00	24.80	0.
124	0	42.00	32.70	0.
125	0	50.00	39.00	0.
126	0	55.00	43.75	0.
127	0	60.00	48.00	0.
128	0	65.00	51.75	0.
129	0	70.00	55.00	0.
130	0	20.00	10.00	0.
131	0	32.00	20.40	0.
132	0	42.00	28.80	0.
133	0	50.00	35.50	0.
134	0	55.00	40.50	0.
135	0	60.00	45.00	0.
136	0	65.00	49.00	0.
137	0	70.00	52.50	0.
138	0	32.00	16.00	0.
139	0	42.00	24.90	0.
140	0	50.00	32.00	0.
141	0	55.00	37.25	0.
142	0	60.00	42.00	0.
143	0	65.00	46.25	0.
144	0	70.00	50.00	0.
145	0	42.00	21.00	0.

146	0	50.00	28.50	0.
147	0	55.00	34.00	0.
148	0	60.00	39.00	0.
149	0	65.00	43.50	0.
150	0	70.00	47.50	0.
151	0	75.00	50.00	0.
152	0	70.00	52.50	0.
153	0	50.00	25.00	0.
154	0	55.00	30.75	0.
155	0	60.00	36.00	0.
156	0	65.00	40.75	0.
157	0	70.00	45.00	0.
158	0	75.00	47.50	0.
159	0	75.00	52.50	0.
160	0	80.00	50.00	0.
161	0	70.00	55.00	0.
162	0	55.00	27.50	0.
163	0	60.00	33.00	0.
164	0	65.00	38.00	0.
165	0	70.00	42.50	0.
166	0	75.00	45.00	0.
167	0	80.00	47.50	0.
168	0	75.00	55.00	0.
169	0	80.00	52.50	0.
170	0	85.00	50.00	0.
171	0	70.00	57.50	0.
172	0	60.00	30.00	0.
173	0	65.00	35.25	0.
174	0	70.00	40.00	0.
175	0	75.00	42.50	0.
176	0	80.00	45.00	0.
177	0	85.00	47.50	0.
178	0	75.00	57.50	0.
179	0	80.00	55.00	0.
180	0	85.00	52.50	0.
181	0	90.00	50.00	0.
182	1	70.00	60.00	60.00
183	0	65.00	32.50	0.
184	0	70.00	37.50	0.
185	0	75.00	40.00	0.
186	0	80.00	42.50	0.
187	0	85.00	45.00	0.
188	0	90.00	47.50	0.
189	1	75.00	60.00	60.00
190	0	80.00	57.50	0.
191	0	85.00	55.00	0.
192	0	90.00	52.50	0.
193	0	95.00	50.00	0.
194	0	70.00	35.00	0.
195	0	75.00	37.50	0.
196	0	80.00	40.00	0.

197	0	85.00	42.50	0.
198	0	90.00	45.00	0.
199	0	95.00	47.50	0.
200	1	80.00	60.00	60.00
201	0	85.00	57.50	0.
202	0	90.00	55.00	0.
203	0	95.00	52.50	0.
204	0	100.00	50.00	0.
205	1	85.00	60.00	60.00
206	0	90.00	57.50	0.
207	0	95.00	55.00	0.
208	0	100.00	52.50	0.
209	0	105.00	52.50	0.
210	1	90.00	60.00	60.00
211	0	95.00	57.50	0.
212	0	100.00	55.00	0.
213	0	105.00	55.00	0.
214	0	110.00	55.00	0.
215	1	95.00	60.00	60.00
216	0	100.00	57.50	0.
217	0	105.00	57.50	0.
218	0	110.00	57.50	0.
219	0	115.00	57.50	0.
220	1	100.00	60.00	60.00
221	1	105.00	60.00	60.00
222	1	110.00	60.00	60.00
223	1	115.00	60.00	60.00
224	1	120.00	60.00	60.00

ELEMENT INFORMATION

ELMT	#1	#2	#3	#4	MAT	ANGLE
1	66	76	87	77	1	26.6
2	76	86	97	87	1	26.6
3	86	96	107	97	1	26.6
4	96	106	117	107	1	26.6
5	106	116	126	117	1	26.6
6	116	125	134	126	1	26.6
7	125	133	141	134	1	26.6
8	133	140	147	141	1	26.6
9	140	146	154	147	1	26.6

10	146	153	162	154	1	26.6
11	77	87	98	88	1	26.6
12	87	97	108	98	1	26.6
13	97	107	118	108	1	26.6
14	107	117	127	118	1	26.6
15	117	126	135	127	1	26.6
16	126	134	142	135	1	26.6
17	134	141	148	142	1	26.6
18	141	147	155	148	1	26.6
19	147	154	163	155	1	26.6
20	154	162	172	163	1	26.6
21	88	98	109	99	1	26.6
22	98	108	119	109	1	26.6
23	108	118	128	119	1	26.6
24	118	127	136	128	1	26.6
25	127	135	143	136	1	26.6
26	135	142	149	143	1	26.6
27	142	148	156	149	1	26.6
28	148	155	164	156	1	26.6
29	155	163	173	164	1	26.6
30	163	172	183	173	1	26.6
31	99	109	120	110	1	26.6
32	109	119	129	120	1	26.6
33	119	128	137	129	1	26.6
34	128	136	144	137	1	26.6
35	136	143	150	144	1	26.6
36	143	149	157	150	1	26.6
37	149	156	165	157	1	26.6
38	156	164	174	165	1	26.6
39	164	173	184	174	1	26.6
40	173	183	194	184	1	26.6
41	153	146	139	145	1	26.6
42	146	140	132	139	1	26.6
43	140	133	124	132	1	26.6
44	133	125	115	124	1	26.6
45	125	116	105	115	1	26.6
46	116	106	95	105	1	26.6
47	106	96	85	95	1	26.6
48	96	86	75	85	1	26.6
49	86	76	65	75	1	26.6
50	76	66	55	65	1	26.6
51	145	139	131	138	1	26.6
52	139	132	123	131	1	26.6
53	132	124	114	123	1	26.6
54	124	115	104	114	1	26.6
55	115	105	94	104	1	26.6
56	105	95	84	94	1	26.6
57	95	85	74	84	1	26.6
58	85	75	64	74	1	26.6
59	75	65	54	64	1	26.6
60	65	55	45	54	1	26.6

61	138	131	122	130	1	26.6
62	131	123	113	122	1	26.6
63	123	114	103	113	1	26.6
64	114	104	93	103	1	26.6
65	104	94	83	93	1	26.6
66	94	84	73	83	1	26.6
67	84	74	63	73	1	26.6
68	74	64	53	63	1	26.6
69	64	54	44	53	1	26.6
70	54	45	36	44	1	26.6
71	130	122	112	121	1	26.6
72	122	113	102	112	1	26.6
73	113	103	92	102	1	26.6
74	103	93	82	92	1	26.6
75	93	83	72	82	1	26.6
76	83	73	62	72	1	26.6
77	73	63	52	62	1	26.6
78	63	53	43	52	1	26.6
79	53	44	35	43	1	26.6
80	44	36	28	35	1	26.6
81	121	112	101	111	1	26.6
82	112	102	91	101	1	26.6
83	102	92	81	91	1	26.6
84	92	82	71	81	1	26.6
85	82	72	61	71	1	26.6
86	72	62	51	61	1	26.6
87	62	52	42	51	1	26.6
88	52	43	34	42	1	26.6
89	43	35	27	34	1	26.6
90	35	28	21	27	1	26.6
91	111	101	90	100	1	26.6
92	101	91	80	90	1	26.6
93	91	81	70	80	1	26.6
94	81	71	60	70	1	26.6
95	71	61	50	60	1	26.6
96	61	51	41	50	1	26.6
97	51	42	33	41	1	26.6
98	42	34	26	33	1	26.6
99	34	27	20	26	1	26.6
100	27	21	15	20	1	26.6
101	100	90	79	89	1	26.6
102	90	80	69	79	1	26.6
103	80	70	59	69	1	26.6
104	70	60	49	59	1	26.6
105	60	50	40	49	1	26.6
106	50	41	32	40	1	26.6
107	41	33	25	32	1	26.6
108	33	26	19	25	1	26.6
109	26	20	14	19	1	26.6
110	20	15	10	14	1	26.6
111	89	79	68	78	1	26.6

112	79	69	58	68	1	26.6
113	69	59	48	58	1	26.6
114	59	49	39	48	1	26.6
115	49	40	31	39	1	26.6
116	40	32	24	31	1	26.6
117	32	25	18	24	1	26.6
118	25	19	13	18	1	26.6
119	19	14	9	13	1	26.6
120	14	10	6	9	1	26.6
121	78	68	57	67	1	26.6
122	68	58	47	57	1	26.6
123	58	48	38	47	1	26.6
124	48	39	30	38	1	26.6
125	39	31	23	30	1	26.6
126	31	24	17	23	1	26.6
127	24	18	12	17	1	26.6
128	18	13	8	12	1	26.6
129	13	9	5	8	1	26.6
130	9	6	3	5	1	26.6
131	67	57	46	56	1	26.6
132	57	47	37	46	1	26.6
133	47	38	29	37	1	26.6
134	38	30	22	29	1	26.6
135	30	23	16	22	1	26.6
136	23	17	11	16	1	26.6
137	17	12	7	11	1	26.6
138	12	8	4	7	1	26.6
139	8	5	2	4	1	26.6
140	5	3	1	2	1	26.6
141	220	216	217	221	1	26.6
142	216	212	213	217	1	26.6
143	212	208	209	213	1	26.6
144	208	204	209	209	1	26.6
145	221	217	218	222	1	26.6
146	217	213	214	218	1	26.6
147	213	209	214	214	1	26.6
148	222	218	219	223	1	26.6
149	218	214	219	219	1	26.6
150	223	219	224	224	1	26.6
151	182	171	178	189	1	26.6
152	171	161	168	178	1	26.6
153	161	152	159	168	1	26.6
154	152	144	151	159	1	26.6
155	189	178	190	200	1	26.6
156	178	168	179	190	1	26.6
157	168	159	169	179	1	26.6
158	159	151	160	169	1	26.6
159	200	190	201	205	1	26.6
160	190	179	191	201	1	26.6
161	179	169	180	191	1	26.6
162	169	160	170	180	1	26.6

163	205	201	206	210	1	26.6
164	201	191	202	206	1	26.6
165	191	180	192	202	1	26.6
166	180	170	181	192	1	26.6
167	210	206	211	215	1	26.6
168	206	202	207	211	1	26.6
169	202	192	203	207	1	26.6
170	192	181	193	203	1	26.6
171	215	211	216	220	1	26.6
172	211	207	212	216	1	26.6
173	207	203	208	212	1	26.6
174	203	193	204	208	1	26.6
175	144	150	158	151	1	26.6
176	150	157	166	158	1	26.6
177	157	165	175	166	1	26.6
178	165	174	185	175	1	26.6
179	174	184	195	185	1	26.6
180	184	194	195	195	1	26.6
181	151	158	167	160	1	26.6
182	158	166	176	167	1	26.6
183	166	175	186	176	1	26.6
184	175	185	196	186	1	26.6
185	185	195	196	196	1	26.6
186	160	167	177	170	1	26.6
187	167	176	187	177	1	26.6
188	176	186	197	187	1	26.6
189	186	196	197	197	1	26.6
190	170	177	188	181	1	26.6
191	177	187	198	188	1	26.6
192	187	197	198	198	1	26.6
193	181	188	199	193	1	26.6
194	188	198	199	199	1	26.6
195	193	199	204	204	1	26.6

NODE	HEAD	PERCENTAGE OF AVAILABLE HEAD	FLOW
1	0.7000E 02	100.0 %	0.9356E-05
2	0.6997E 02	99.7 %	
3	0.7000E 02	100.0 %	0.5691E-04
4	0.6989E 02	98.9 %	
5	0.6993E 02	99.3 %	
6	0.7000E 02	100.0 %	0.1094E-03
7	0.6974E 02	97.4 %	
8	0.6981E 02	98.1 %	
9	0.6990E 02	99.0 %	
10	0.7000E 02	100.0 %	0.1542E-03
11	0.6954E 02	95.4 %	
12	0.6964E 02	96.4 %	
13	0.6975E 02	97.5 %	
14	0.6987E 02	98.7 %	
15	0.7000E 02	100.0 %	0.1955E-03
16	0.6928E 02	92.8 %	
17	0.6943E 02	94.3 %	
18	0.6956E 02	95.6 %	
19	0.6970E 02	97.0 %	
20	0.6985E 02	98.5 %	
21	0.7000E 02	100.0 %	0.2393E-03
22	0.6900E 02	90.0 %	
23	0.6918E 02	91.8 %	
24	0.6933E 02	93.3 %	
25	0.6948E 02	94.8 %	
26	0.6964E 02	96.4 %	
27	0.6981E 02	98.1 %	
28	0.7000E 02	100.0 %	0.2921E-03
29	0.6874E 02	87.4 %	
30	0.6891E 02	89.1 %	
31	0.6907E 02	90.7 %	
32	0.6922E 02	92.2 %	
33	0.6939E 02	93.9 %	
34	0.6957E 02	95.7 %	
35	0.6977E 02	97.7 %	
36	0.7000E 02	100.0 %	0.3613E-03
37	0.6853E 02	85.3 %	
38	0.6867E 02	86.7 %	
39	0.6880E 02	88.0 %	
40	0.6894E 02	89.4 %	
41	0.6909E 02	90.9 %	
42	0.6927E 02	92.7 %	
43	0.6947E 02	94.7 %	
44	0.6971E 02	97.1 %	
45	0.7000E 02	100.0 %	0.4591E-03
46	0.6840E 02	84.0 %	
47	0.6848E 02	84.8 %	
48	0.6856E 02	85.6 %	

49	0.6864E 02	86.4 %	
50	0.6876E 02	87.6 %	
51	0.6890E 02	89.0 %	
52	0.6909E 02	90.9 %	
53	0.6931E 02	93.1 %	
54	0.6961E 02	96.1 %	
55	0.7000E 02	100.0 %	0.6351E-03
56	0.6836E 02	83.6 %	
57	0.6837E 02	83.7 %	
58	0.6837E 02	83.7 %	
59	0.6838E 02	83.8 %	
60	0.6843E 02	84.3 %	
61	0.6851E 02	85.1 %	
62	0.6863E 02	86.3 %	
63	0.6881E 02	88.1 %	
64	0.6905E 02	90.5 %	
65	0.6940E 02	94.0 %	
66	0.7000E 02	100.0 %	0.1127E-02
67	0.6834E 02	83.4 %	
68	0.6826E 02	82.6 %	
69	0.6819E 02	81.9 %	
70	0.6814E 02	81.4 %	
71	0.6813E 02	81.3 %	
72	0.6816E 02	81.6 %	
73	0.6823E 02	82.3 %	
74	0.6833E 02	83.3 %	
75	0.6843E 02	84.3 %	
76	0.6845E 02	84.5 %	
77	0.6850E 02	85.0 %	
78	0.6824E 02	82.4 %	
79	0.6808E 02	80.8 %	
80	0.6793E 02	79.3 %	
81	0.6782E 02	78.2 %	
82	0.6774E 02	77.4 %	
83	0.6770E 02	77.0 %	
84	0.6768E 02	76.8 %	
85	0.6767E 02	76.7 %	
86	0.6766E 02	76.6 %	
87	0.6777E 02	77.7 %	
88	0.6768E 02	76.8 %	
89	0.6807E 02	80.7 %	
90	0.6782E 02	78.2 %	
91	0.6759E 02	75.9 %	
92	0.6740E 02	74.0 %	
93	0.6724E 02	72.4 %	
94	0.6712E 02	71.2 %	
95	0.6703E 02	70.3 %	
96	0.6700E 02	70.0 %	
97	0.6714E 02	71.4 %	
98	0.6716E 02	71.6 %	
99	0.6704E 02	70.4 %	

100	0.6782E 02	78.2 %
101	0.6748E 02	74.8 %
102	0.6717E 02	71.7 %
103	0.6689E 02	68.9 %
104	0.6666E 02	66.6 %
105	0.6648E 02	64.8 %
106	0.6638E 02	63.8 %
107	0.6653E 02	65.3 %
108	0.6664E 02	66.4 %
109	0.6667E 02	66.7 %
110	0.6663E 02	66.3 %
111	0.6749E 02	74.9 %
112	0.6706E 02	70.6 %
113	0.6667E 02	66.7 %
114	0.6631E 02	63.1 %
115	0.6602E 02	60.2 %
116	0.6582E 02	58.2 %
117	0.6591E 02	59.1 %
118	0.6603E 02	60.3 %
119	0.6617E 02	61.7 %
120	0.6628E 02	62.8 %
121	0.6708E 02	70.8 %
122	0.6657E 02	65.7 %
123	0.6610E 02	61.0 %
124	0.6570E 02	57.0 %
125	0.6537E 02	53.7 %
126	0.6532E 02	53.2 %
127	0.6534E 02	53.4 %
128	0.6547E 02	54.7 %
129	0.6571E 02	57.1 %
130	0.6659E 02	65.9 %
131	0.6602E 02	60.2 %
132	0.6552E 02	55.2 %
133	0.6509E 02	50.9 %
134	0.6489E 02	48.9 %
135	0.6470E 02	47.0 %
136	0.6461E 02	46.1 %
137	0.6491E 02	49.1 %
138	0.6606E 02	60.6 %
139	0.6546E 02	54.6 %
140	0.6496E 02	49.6 %
141	0.6465E 02	46.5 %
142	0.6432E 02	43.2 %
143	0.6386E 02	38.6 %
144	0.6303E 02	30.3 %
145	0.6550E 02	55.0 %
146	0.6493E 02	49.3 %
147	0.6456E 02	45.6 %
148	0.6418E 02	41.8 %
149	0.6373E 02	37.3 %
150	0.6309E 02	30.9 %

151	0.6228E 02	22.8 %	
152	0.6127E 02	12.7 %	
153	0.6499E 02	49.9 %	
154	0.6456E 02	45.6 %	
155	0.6414E 02	41.4 %	
156	0.6368E 02	36.8 %	
157	0.6313E 02	31.3 %	
158	0.6250E 02	25.0 %	
159	0.6190E 02	19.0 %	
160	0.6190E 02	19.0 %	
161	0.6052E 02	5.2 %	
162	0.6463E 02	46.3 %	
163	0.6416E 02	41.6 %	
164	0.6370E 02	37.0 %	
165	0.6318E 02	31.8 %	
166	0.6265E 02	26.5 %	
167	0.6211E 02	21.1 %	
168	0.6096E 02	9.6 %	
169	0.6159E 02	15.9 %	
170	0.6160E 02	16.0 %	
171	0.6012E 02	1.2 %	
172	0.6424E 02	42.4 %	
173	0.6374E 02	37.4 %	
174	0.6324E 02	32.4 %	
175	0.6275E 02	27.5 %	
176	0.6227E 02	22.7 %	
177	0.6180E 02	18.0 %	
178	0.6034E 02	3.4 %	
179	0.6115E 02	11.5 %	
180	0.6135E 02	13.5 %	
181	0.6135E 02	13.5 %	
182	0.6000E 02	0. %	-0.3593E-04
183	0.6382E 02	38.2 %	
184	0.6331E 02	33.1 %	
185	0.6285E 02	28.5 %	
186	0.6239E 02	23.9 %	
187	0.6194E 02	19.4 %	
188	0.6151E 02	15.1 %	
189	0.6000E 02	0. %	-0.2296E-03
190	0.6051E 02	5.1 %	
191	0.6100E 02	10.0 %	
192	0.6113E 02	11.3 %	
193	0.6111E 02	11.1 %	
194	0.6339E 02	33.9 %	
195	0.6294E 02	29.4 %	
196	0.6248E 02	24.8 %	
197	0.6204E 02	20.4 %	
198	0.6161E 02	16.1 %	
199	0.6121E 02	12.1 %	
200	0.6000E 02	0. %	-0.4520E-03
201	0.6054E 02	5.4 %	

202	0.6085E 02	8,5 %	
203	0.6094E 02	9.4 %	
204	0.6085E 02	8.5 %	
205	0.6000E 02	0. %	-0.5883E-03
206	0.6047E 02	4.7 %	
207	0.6071E 02	7.1 %	
208	0.6075E 02	7.5 %	
209	0.6054E 02	5.4 %	
210	0.6000E 02	0. %	-0.5865E-03
211	0.6040E 02	4.0 %	
212	0.6058E 02	5.8 %	
213	0.6045E 02	4.5 %	
214	0.6028E 02	2.8 %	
215	0.6000E 02	0, %	-0.5019E-03
216	0.6033E 02	3.3 %	
217	0.6026E 02	2.6 %	
218	0.6019E 02	1.9 %	
219	0.6009E 02	0.9 %	
220	0.6000E 02	0. %	-0.4216E-03
221	0.6000E 02	0. %	-0.3453E-03
222	0.6000E 02	0. %	-0.2668E-03
223	0.6000E 02	0. %	-0.1787E-03
224	0.6000E 02	0. %	-0.3207E-04

ELEMENT FLOW RATES

ELMT	V1	V2	P-AXIS ANG	RES V	DIR OF V
1	0.102E-03	-0.881E-04	0.266E 02	0.135E-03	-0.143E 02
2	0.520E-04	-0.546E-04	0.266E 02	0.754E-04	-0.199E 02
3	0.493E-04	-0.485E-04	0.266E 02	0.692E-04	-0.180E 02
4	0.608E-04	-0.482E-04	0.266E 02	0.776E-04	-0.118E 02
5	0.896E-04	-0.467E-04	0.266E 02	0.101E-03	-0.974E 00
6	0.122E-03	-0.387E-04	0.266E 02	0.128E-03	0.901E 01
7	0.139E-03	-0.264E-04	0.266E 02	0.142E-03	0.158E 02
8	0.138E-03	-0.159E-04	0.266E 02	0.139E-03	0.200E 02
9	0.133E-03	-0.856E-05	0.266E 02	0.134E-03	0.229E 02
10	0.129E-03	-0.272E-05	0.266E 02	0.129E-03	0.254E 02
11	0.865E-04	-0.532E-04	0.266E 02	0.102E-03	-0.501E 01
12	0.565E-04	-0.484E-04	0.266E 02	0.744E-04	-0,140E 02
13	0.477E-04	-0.500E-04	0.266E 02	0.691E-04	-0.198E 02
14	0.667E-04	-0.552E-04	0.266E 02	0.866E-04	-0.130E 02

15	0.113E-03	-0.543E-04	0.266E 02	0.125E-03	0.864E 00
16	0.157E-03	-0.406E-04	0.266E 02	0.162E-03	0.120E 02
17	0.165E-03	-0.236E-04	0.266E 02	0.166E-03	0.184E 02
18	0.153E-03	-0.137E-04	0.266E 02	0.153E-03	0.215E 02
19	0.144E-03	-0.733E-05	0.266E 02	0.145E-03	0.237E 02
20	0.139E-03	-0.233E-05	0.266E 02	0.139E-03	0.256E 02
21	0.690E-04	-0.417E-04	0.266E 02	0.806E-04	-0.460E 01
22	0.376E-04	-0.455E-04	0.266E 02	0.590E-04	-0.239E 02
23	0.329E-04	-0.572E-04	0.266E 02	0.660E-04	-0.335E 02
24	0.738E-04	-0.701E-04	0.266E 02	0.102E-03	-0.170E 02
25	0.160E-03	-0.678E-04	0.266E 02	0.174E-03	0.361E 01
26	0.216E-03	-0.342E-04	0.266E 02	0.219E-03	0.176E 02
27	0.183E-03	-0.178E-04	0.266E 02	0.184E-03	0.210E 02
28	0.165E-03	-0.104E-04	0.266E 02	0.165E-03	0.230E 02
29	0.154E-03	-0.561E-05	0.266E 02	0.154E-03	0.245E 02
30	0.148E-03	-0.181E-05	0.266E 02	0.148E-03	0.259E 02
31	0.266E-04	-0.353E-04	0.266E 02	0.442E-04	-0.264E 02
32	-0.276E-05	-0.497E-04	0.266E 02	0.497E-04	-0.666E 02
33	-0.792E-05	-0.689E-04	0.266E 02	0.693E-04	-0.700E 02
34	0.771E-04	-0.132E-03	0.266E 02	0.153E-03	-0.332E 02
35	0.352E-03	-0.512E-04	0.266E 02	0.356E-03	0.183E 02
36	0.233E-03	-0.178E-04	0.266E 02	0.234E-03	0.222E 02
37	0.195E-03	-0.104E-04	0.266E 02	0.195E-03	0.235E 02
38	0.173E-03	-0.626E-05	0.266E 02	0.173E-03	0.245E 02
39	0.161E-03	-0.353E-05	0.266E 02	0.161E-03	0.253E 02
40	0.155E-03	-0.114E-05	0.266E 02	0.155E-03	0.261E 02
41	0.116E-03	-0.301E-05	0.266E 02	0.116E-03	0.251E 02
42	0.118E-03	-0.940E-05	0.266E 02	0.119E-03	0.220E 02
43	0.119E-03	-0.170E-04	0.266E 02	0.120E-03	0.184E 02
44	0.113E-03	-0.263E-04	0.266E 02	0.116E-03	0.134E 02
45	0.947E-04	-0.351E-04	0.266E 02	0.101E-03	0.619E 01
46	0.701E-04	-0.409E-04	0.266E 02	0.812E-04	-0.371E 01
47	0.490E-04	-0.441E-04	0.266E 02	0.659E-04	-0.154E 02
48	0.332E-04	-0.485E-04	0.266E 02	0.588E-04	-0.290E 02
49	0.111E-04	-0.590E-04	0.266E 02	0.600E-04	-0.528E 02
50	-0.138E-03	-0.634E-04	0.266E 02	0.152E-03	-0.129E 03
51	0.985E-04	-0.310E-05	0.266E 02	0.985E-04	0.248E 02
52	0.990E-04	-0.962E-05	0.266E 02	0.995E-04	0.210E 02
53	0.957E-04	-0.168E-04	0.266E 02	0.971E-04	0.166E 02
54	0.858E-04	-0.244E-04	0.266E 02	0.892E-04	0.107E 02
55	0.689E-04	-0.309E-04	0.266E 02	0.755E-04	0.240E 01
56	0.484E-04	-0.357E-04	0.266E 02	0.601E-04	-0.983E 01
57	0.262E-04	-0.395E-04	0.266E 02	0.474E-04	-0.298E 02
58	-0.425E-05	-0.431E-04	0.266E 02	0.433E-04	-0.691E 02
59	-0.653E-04	-0.415E-04	0.266E 02	0.774E-04	-0.121E 03
60	-0.818E-04	-0.247E-04	0.266E 02	0.855E-04	-0.137E 03
61	0.797E-04	-0.295E-05	0.266E 02	0.797E-04	0.244E 02
62	0.789E-04	-0.908E-05	0.266E 02	0.794E-04	0.200E 02
63	0.735E-04	-0.154E-04	0.266E 02	0.751E-04	0.147E 02
64	0.626E-04	-0.215E-04	0.266E 02	0.662E-04	0.762E 01
65	0.465E-04	-0.265E-04	0.266E 02	0.535E-04	-0.310E 01

66	0.263E-04	-0.301E-04	0.266E 02	0.399E-04	-0.223E 02
67	0.915E-06	-0.319E-04	0.266E 02	0.319E-04	-0.618E 02
68	-0.314E-04	-0.300E-04	0.266E 02	0.434E-04	-0.110E 03
69	-0.490E-04	-0.222E-04	0.266E 02	0.537E-04	-0.129E 03
70	-0.530E-04	-0.148E-04	0.266E 02	0.550E-04	-0.138E 03
71	0.617E-04	-0.263E-05	0.266E 02	0.618E-04	0.241E 02
72	0.602E-04	-0.804E-05	0.266E 02	0.608E-04	0.190E 02
73	0.541E-04	-0.134E-04	0.266E 02	0.558E-04	0.127E 02
74	0.432E-04	-0.181E-04	0.266E 02	0.469E-04	0.380E 01
75	0.279E-04	-0.217E-04	0.266E 02	0.353E-04	-0.113E 02
76	0.881E-05	-0.235E-04	0.266E 02	0.251E-04	-0.429E 02
77	-0.123E-04	-0.227E-04	0.266E 02	0.258E-04	-0.918E 02
78	-0.277E-04	-0.188E-04	0.266E 02	0.335E-04	-0.119E 03
79	-0.352E-04	-0.140E-04	0.266E 02	0.379E-04	-0.132E 03
80	-0.364E-04	-0.975E-05	0.266E 02	0.377E-04	-0.138E 03
81	0.459E-04	-0.224E-05	0.266E 02	0.460E-04	0.238E 02
82	0.442E-04	-0.680E-05	0.266E 02	0.447E-04	0.178E 02
83	0.382E-04	-0.111E-04	0.266E 02	0.398E-04	0.103E 02
84	0.280E-04	-0.147E-04	0.266E 02	0.317E-04	-0.109E 01
85	0.146E-04	-0.169E-04	0.266E 02	0.223E-04	-0.227E 02
86	-0.499E-06	-0.173E-04	0.266E 02	0.173E-04	-0.651E 02
87	-0.135E-04	-0.156E-04	0.266E 02	0.206E-04	-0.104E 03
88	-0.220E-04	-0.126E-04	0.266E 02	0.253E-04	-0.123E 03
89	-0.256E-04	-0.951E-05	0.266E 02	0.273E-04	-0.133E 03
90	-0.260E-04	-0.682E-05	0.266E 02	0.269E-04	-0.139E 03
91	0.328E-04	-0.185E-05	0.266E 02	0.329E-04	0.233E 02
92	0.311E-04	-0.557E-05	0.266E 02	0.316E-04	0.164E 02
93	0.257E-04	-0.898E-05	0.266E 02	0.272E-04	0.732E 01
94	0.171E-04	-0.115E-04	0.266E 02	0.206E-04	-0.748E 01
95	0.645E-05	-0.128E-04	0.266E 02	0.143E-04	-0.367E 02
96	-0.401E-05	-0.125E-04	0.266E 02	0.132E-04	-0.812E 02
97	-0.122E-04	-0.110E-04	0.266E 02	0.164E-04	-0.111E 03
98	-0.170E-04	-0.890E-05	0.266E 02	0.192E-04	-0.126E 03
99	-0.190E-04	-0.677E-05	0.266E 02	0.201E-04	-0.134E 03
100	-0.190E-04	-0.493E-05	0.266E 02	0.196E-04	-0.139E 03
101	0.223E-04	-0.150E-05	0.266E 02	0.224E-04	0.227E 02
102	0.208E-04	-0.450E-05	0.266E 02	0.213E-04	0.144E 02
103	0.164E-04	-0.715E-05	0.266E 02	0.179E-04	0.298E 01
104	0.961E-05	-0.899E-05	0.266E 02	0.132E-04	-0.165E 02
105	0.186E-05	-0.971E-05	0.266E 02	0.988E-05	-0.526E 02
106	-0.519E-05	-0.930E-05	0.266E 02	0.107E-04	-0.926E 02
107	-0.103E-04	-0.810E-05	0.266E 02	0.131E-04	-0.115E 03
108	-0.131E-04	-0.655E-05	0.266E 02	0.146E-04	-0.127E 03
109	-0.141E-04	-0.500E-05	0.266E 02	0.149E-04	-0.134E 03
110	-0.139E-04	-0.362E-05	0.266E 02	0.143E-04	-0.139E 03
111	0.140E-04	-0.123E-05	0.266E 02	0.140E-04	0.215E 02
112	0.128E-04	-0.366E-05	0.266E 02	0.134E-04	0.106E 02
113	0.947E-05	-0.575E-05	0.266E 02	0.111E-04	-0.472E 01
114	0.454E-05	-0.713E-05	0.266E 02	0.845E-05	-0.310E 02
115	-0.783E-06	-0.759E-05	0.266E 02	0.763E-05	-0.693E 02
116	-0.530E-05	-0.720E-05	0.266E 02	0.894E-05	-0.998E 02

117	-0.832E-05	-0.624E-05	0.266E 02	0.104E-04	-0.117E 03
118	-0.979E-05	-0.503E-05	0.266E 02	0.110E-04	-0.126E 03
119	-0.101E-04	-0.378E-15	0.266E 02	0.108E-04	-0.133E 03
120	-0.969E-05	-0.261E-05	0.266E 02	0.100E-04	-0.138E 03
121	0.730E-05	-0.103E-05	0.266E 02	0.737E-05	0.185E 02
122	0.654E-05	-0.307E-05	0.266E 02	0.722E-05	0.144E 01
123	0.421E-05	-0.481E-05	0.266E 02	0.639E-05	-0.222E 02
124	0.978E-06	-0.593E-05	0.266E 02	0.601E-05	-0.541E 02
125	-0.226E-05	-0.627E-05	0.266E 02	0.667E-05	-0.832E 02
126	-0.475E-05	-0.592E-05	0.266E 02	0.759E-05	-0.102E 03
127	-0.617E-05	-0.508E-05	0.266E 02	0.800E-05	-0.114E 03
128	-0.662E-05	-0.400E-05	0.266E 02	0.774E-05	-0.122E 03
129	-0.641E-05	-0.286E-05	0.266E 02	0.702E-05	-0.129E 03
130	-0.583E-05	-0.174E-05	0.266E 02	0.608E-05	-0.137E 03
131	0.188E-05	-0.833E-06	0.266E 02	0.206E-05	0.271E 01
132	0.123E-05	-0.267E-05	0.266E 02	0.294E-05	-0.387E 02
133	-0.136E-06	-0.432E-05	0.266E 02	0.432E-05	-0.652E 02
134	-0.163E-05	-0.537E-05	0.266E 02	0.561E-05	-0.803E 02
135	-0.282E-05	-0.565E-05	0.266E 02	0.632E-05	-0.899E 02
136	-0.346E-05	-0.524E-05	0.266E 02	0.628E-05	-0.969E 02
137	-0.354E-05	-0.436E-05	0.266E 02	0.561E-05	-0.103E 03
138	-0.322E-05	-0.324E-05	0.266E 02	0.457E-05	-0.108E 03
139	-0.268E-05	-0.205E-05	0.266E 02	0.337E-05	-0.116E 03
140	-0.203E-05	-0.903E-06	0.266E 02	0.222E-05	-0.129E 03
141	0.116E-03	0.225E-04	0.266E 02	0.118E-03	0.376E 02
142	0.111E-03	0.149E-04	0.266E 02	0.112E-03	0.342E 02
143	0.109E-03	0.697E-05	0.266E 02	0.109E-03	0.302E 02
144	0.110E-03	0.323E-05	0.266E 02	0.110E-03	0.282E 02
145	0.927E-04	0.171E-04	0.266E 02	0.942E-04	0.370E 02
146	0.893E-04	0.823E-05	0.266E 02	0.897E-04	0.318E 02
147	0.905E-04	0.387E-05	0.266E 02	0.906E-04	0.290E 02
148	0.675E-04	0.101E-04	0.266E 02	0.683E-04	0.351E 02
149	0.661E-04	0.489E-05	0.266E 02	0.662E-04	0.308E 02
150	0.323E-04	0.717E-05	0.266E 02	0.331E-04	0.391E 02
151	0.423E-04	0.200E-04	0.266E 02	0.468E-04	0.519E 02
152	0.629E-04	0.461E-04	0.266E 02	0.779E-04	0.628E 02
153	0.110E-03	0.769E-04	0.266E 02	0.134E-03	0.615E 02
154	0.396E-03	0.823E-04	0.266E 02	0.405E-03	0.383E 02
155	0.119E-03	0.347E-04	0.266E 02	0.124E-03	0.429E 02
156	0.158E-03	0.530E-04	0.266E 02	0.166E-03	0.451E 02
157	0.264E-03	0.530E-04	0.266E 02	0.269E-03	0.379E 02
158	0.242E-03	0.201E-04	0.266E 02	0.243E-03	0.313E 02
159	0.179E-03	0.415E-04	0.266E 02	0.183E-03	0.397E 02
160	0.214E-03	0.417E-04	0.266E 02	0.218E-03	0.376E 02
161	0.209E-03	0.269E-04	0.266E 02	0.211E-03	0.339E 02
162	0.195E-03	0.170E-04	0.266E 02	0.196E-03	0.316E 02
163	0.192E-03	0.389E-04	0.266E 02	0.196E-03	0.380E 02
164	0.185E-03	0.301E-04	0.266E 02	0.188E-03	0.358E 02
165	0.176E-03	0.215E-04	0.266E 02	0.178E-03	0.335E 02
166	0.166E-03	0.141E-04	0.266E 02	0.166E-03	0.314E 02
167	0.165E-03	0.332E-04	0.266E 02	0.168E-03	0.379E 02

168	0.158E-03	0.249E-04	0.266E 02	0.160E-03	0.355E 02
169	0.150E-03	0.173E-04	0.266E 02	0.151E-03	0.331E 02
170	0.144E-03	0.108E-04	0.266E 02	0.144E-03	0.309E 02
171	0.140E-03	0.277E-04	0.266E 02	0.142E-03	0.378E 02
172	0.134E-03	0.201E-04	0.266E 02	0.135E-03	0.351E 02
173	0.128E-03	0.129E-04	0.266E 02	0.129E-03	0.323E 02
174	0.126E-03	0.587E-05	0.266E 02	0.126E-03	0.292E 02
175	0.288E-03	-0.155E-05	0.266E 02	0.288E-03	0.263E 02
176	0.220E-03	-0.362E-05	0.266E 02	0.220E-03	0.256E 02
177	0.188E-03	-0.267E-05	0.266E 02	0.188E-03	0.257E 02
178	0.171E-03	-0.195E-05	0.266E 02	0.171E-03	0.259E 02
179	0.162E-03	-0.118E-05	0.266E 02	0.162E-03	0.261E 02
180	0.158E-03	-0.783E-06	0.266E 02	0.158E-03	0.263E 02
181	0.213E-03	0.970E-05	0.266E 02	0.213E-03	0.292E 02
182	0.188E-03	0.401E-05	0.266E 02	0.188E-03	0.278E 02
183	0.171E-03	0.166E-05	0.266E 02	0.171E-03	0.271E 02
184	0.162E-03	0.363E-06	0.266E 02	0.162E-03	0.267E 02
185	0.160E-03	-0.249E-07	0.266E 02	0.160E-03	0.266E 02
186	0.179E-03	0.977E-05	0.266E 02	0.179E-03	0.297E 02
187	0.166E-03	0.524E-05	0.266E 02	0.166E-03	0.284E 02
188	0.159E-03	0.198E-05	0.266E 02	0.159E-03	0.273E 02
189	0.157E-03	0.744E-06	0.266E 02	0.157E-03	0.268E 02
190	0.156E-03	0.828E-05	0.266E 02	0.157E-03	0.296E 02
191	0.151E-03	0.346E-05	0.266E 02	0.151E-03	0.279E 02
192	0.151E-03	0.147E-05	0.266E 02	0.151E-03	0.271E 02
193	0.140E-03	0.474E-05	0.266E 02	0.140E-03	0.285E 02
194	0.140E-03	0.211E-05	0.266E 02	0.140E-03	0.274E 02
195	0.127E-03	0.268E-05	0.266E 02	0.127E-03	0.278E 02

38. Figure 20 is the equipotential plot, and Figure 21 is the velocity vector plot.

Analysis

39. This problem can be solved graphically by transformation and then construction of a flow net. Using a shape factor of the transformed problem of 1/2, the rate of seepage per linear foot of structure is 3.2808 (10^{-3}) cfm. The flow from the computer run is 3.6387 (10^{-3}) cfm, giving a percent difference of 10.3.

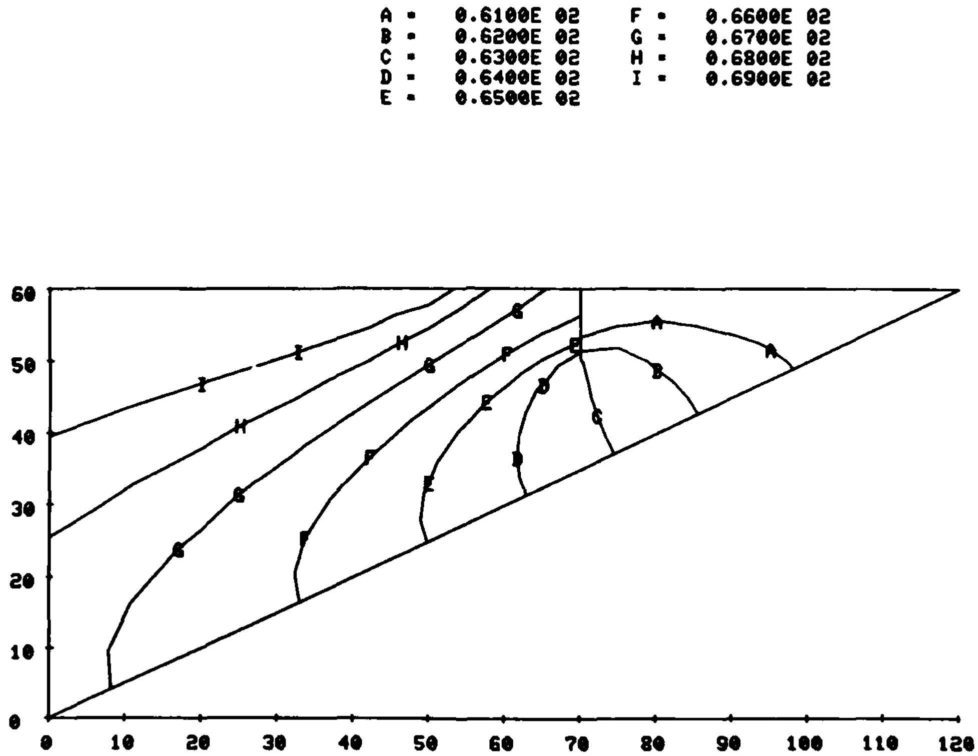

Figure 20. Equipotential line plot

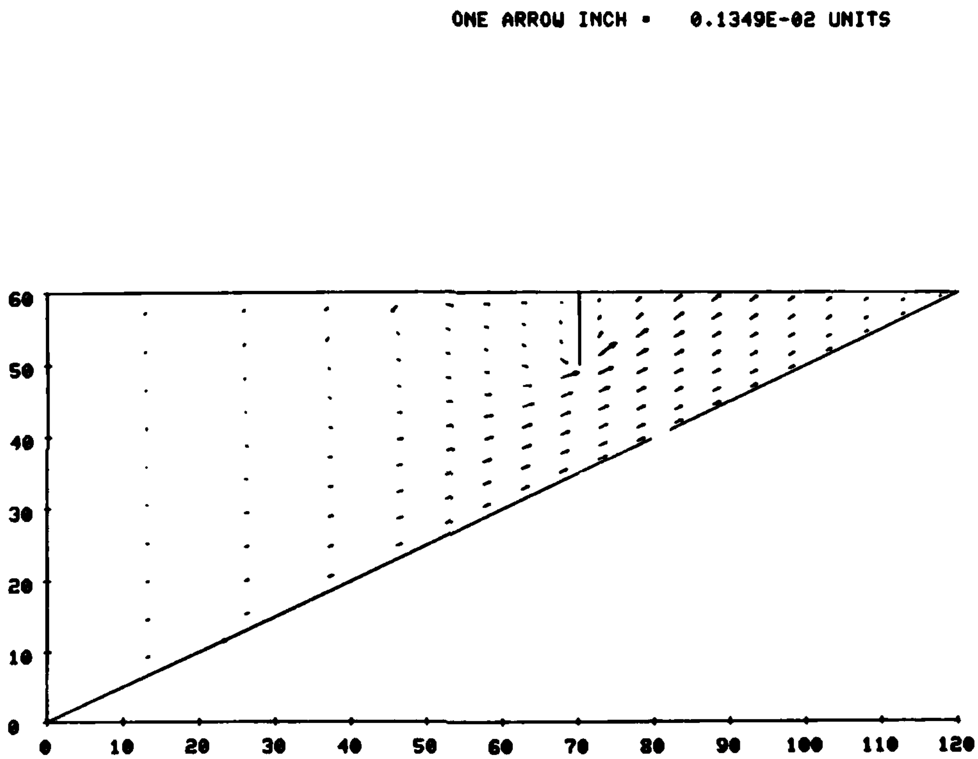

Figure 21. Velocity vector plot

APPENDIX A: PROCEDURE FOR UNCONFINED FLOW PROBLEMS

1. Determination of the phreatic surface in this computer program is based on a modification of work by Bathe and Khashgoftaar.* An outline of the procedure used in the program is as follows:

   a. Assume an initial position of the phreatic surface at the highest possible elevation.

   b. Compute heads and flows for each node, satisfying only the flow = 0 condition on the phreatic surface.

   c. Assume all points whose computed pressure is less than zero to be above the phreatic surface. To model the "no flow" condition of these nodes, assume very small permeabilities in the region of these points.

   d. Using the new permeabilities, compute a new set of flows at the nodes. All internal nodes should have zero flows (where there are no sources or sinks). Compute a set of Δh's to make these flows vanish, and compute head at node i as $h_{i\ new} = h_{i\ old} + \Delta h_i$.

   e. Repeat the iterative process of steps c and d until the maximum h is of acceptable smallness.

2. Now, an element whose nodes have all negative pressures is completely above the phreatic surface, and an element whose nodes have some positive pressures or negative pressures has the phreatic surface passing through it. Linear interpolation is used to determine the modified shapes of the affected elements (see Figures 7, 11, and 14 in the main text) and the position of the phreatic surface.

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* Bathe, K.-J., and Khashgoftaar, M. R. 1979. "Finite Element Free Surface Analysis without Mesh Iteration," International Journal of Numerical and Analytical Methods in Geomechanics, Vol 3, pp 13-22.